JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol. 30 JUNE 1937 No. 3

Contents

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American Association of Economic Entomologists

Paper-reading Session, Forty-ninth Annual Meeting, Atlantic City, N. J.

Grenz Radiographs of Sulfur Dispersion on Foliage, G. F. MACLEOD and H. F. SHERWOOD . . . 395
Stickers Used with Calcium and Zinc Arsenates, FRANKLIN SHERMAN III . . . 398
Adherence and Rate of Settling of Lead Arsenate Dusts for Autogiro and Airplane Application, CLYDE C. HAMILTON . . . 399
Stickers and Spreaders Used in Lead Arsenate Sprays for Codling Moth Control, S. W. HARMAN . . . 404
Five Years' Experiments with Lead Arsenate–Summer Oil in Codling Moth Control, BYRLEY F. DRIGGERS . . . 407
Effect of Certain Codling Moth Spray Schedules on Other Orchard Insects, C. R. CUTRIGHT . . . 413
Tests with Bait and Light to Trap Codling Moth, HARLAN N. WORTHLEY and J. E. NICHOLAS . . . 417
Effects of Light Traps on a Codling Moth Infestation, A Consideration of Four Years' Data, DONALD L. COLLINS and WILLIAM MACHADO . . . 422
Effect of Different Spreaders on Thrips Control by Nicotine, C. O. EDDY and S. S. SHARP . . . 427
Karaya Gum in Nicotine Sprays, C. O. EDDY and C. M. MEADOWS . . . 430
Experiments to Control Hairy Chinch Bug Infesting Turf on Long Island, G. F. MACLEOD and KENNETH E. MAXWELL . . . 432
Dusting to Control Strawberry Weevil in Virginia, L. D. ANDERSON and H. G. WALKER . . . 437
Pea Aphid Control in Maryland, C. GRAHAM . . . 439
Control of Larvae of Diamondback Moth, *Plutella maculipennis* Curtis, HARRY G. WALKER and LAUREN D. ANDERSON . . . 443
The Hollyhock Thrips, *Liothrips varicornis* Hood, STANLEY F. BAILEY . . . 448
Lineodes integra Zell., A Potential Pest of Greenhouse Tomatoes, C. C. COMPTON . . . 451
White Coating on Foliage a Repellent for Potato Leafhopper, E. I. MCDANIEL . . . 454
Dissemination of Insects by Air Currents, E. P. FELT . . . 458
Use of Illustrative Material in Presenting Subject Matter, M. P. JONES . . . 461

●

Eastern Branch

Paper-reading Session, Eighth Annual Meeting, New York, N. Y.

Particle Size of Commercial Calcium Arsenates by Sedimentation Analysis, LYLE D. GOODHUE . . . 466
An Examination of Commercial Calcium Arsenates, O. A. NELSON and C. C. CASSIL . . . 474
Tests of Cattle Fly Sprays by the "One-half Cow" Method, DONALD MACCREARY and A. H. GODDIN . . . 478

●

Pacific Slope Branch

Paper-reading Session, Twenty-first Annual Meeting, Seattle, Wash.

Effects of Subzero Temperatures on Populations of Western Pine Beetle, *Dendroctonus brevicomis* Lec., F. P. KEEN and R. L. FURNISS . . . 482

●

American Association of Economic Entomologists
Paper-reading Session, Forty-eighth Annual Meeting, St. Louis, Mo.

Testing for Resistance to American Foulbrood in Honeybees, O. W. PARK 504

●

Current Contributions

Improved Control of Red Spider on Greenhouse Crops, With Sulfur and Cyclohexylamine Derivatives, C. C. COMPTON and C. W. KEARNS 512
An Insect that Breathes Through Its Nose, R. C. ROARK 522

●

Common Names of Insects Approved for General Use by the American Association of Economic Entomologists 527
Scientific Notes 560
Editorial 565
Reviews 566
Obituary 568
Current Notes 569
Horticultural Inspection Notes 438, 457, 569, 570

NOTICE

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JOURNAL
OF ECONOMIC ENTOMOLOGY
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Vol. 30 JUNE 1937 No. 3

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

PAPER-READING SESSION, FORTY-NINTH ANNUAL MEETING
Atlantic City, N. J., December 1936

Grenz Radiographs of Sulfur Dispersion on Foliage

G. F. MACLEOD, *Cornell University, Ithaca, N. Y.*, and H. F. SHERWOOD, *Eastman Kodak Company, Rochester, N. Y.*[1]

PROBLEMS involved in studies of insecticidal residues on plants are recognized as complicated but important parts of field experiments. A matter of considerable importance in this connection is the dispersion or coverage of sprays as contrasted with the amount when determined by chemical analyses. Two leaves may bear the same total amount of spray material yet in no way be comparably protected so far as dispersion is concerned. In the course of some general investigations regarding sulfur as an insecticide the need for a rapid, accurate method of depicting sulfur residues on foliage led to preliminary tests with Grenz-ray radiography. The results were sufficiently interesting to warrant presentation of the method although the findings regarding sulfur residues are as yet more suggestive than conclusive.

A number of mature leaves were selected at random from Baldwin apple trees and sprayed in the laboratory with mixtures of 325-mesh unconditioned pure sulfur in solutions of wetting agents as follows:

1	Sulfur	14 gms.	2	Sulfur	14 gms.	3	Sulfur	14 gms.
	Soap[2]	2 gms.		*Areskap*[3]	2 gms.		*Mouillant M*[4]	2 cc.
	Distilled water	1000 cc.		Distilled water	1000 cc.		Distilled water	1000 cc.

The mixtures were prepared by adding first the wetting agent, then the sulfur and finally stirring all mixtures for the same length of time with a mechanical mixer. The various wetting agents at the strengths used produced visibly different types of sulfur suspension in water. The soap solution held sulfur particles in suspension longer and wet the material easier than either the *Areskap* or *Mouillant*. *Mouillant* caused a distinct flocculation of sulfur particles and even after standing a week

[1] Studies conducted at the Eastman Kodak Research Laboratories, Rochester, N. Y.
[2] Soap-water 13 per cent, unsaponifiable matter other than pine tar 2 per cent.
[3] *Areskap Dry 100*, sample No. 8-B, 3-5-5-36.
[4] *No. 20582*, an alkyl-aromatic sulfate.

much of the sulfur remained unwetted and floated on top of the mixture. *Areskap* wet the sulfur slowly but thoroughly.

A *Hudson* electric atomizer sprayer was used and all leaves were sprayed under the same standardized conditions. Separate leaves were used to study the deposit on upper and lower surfaces, one series being

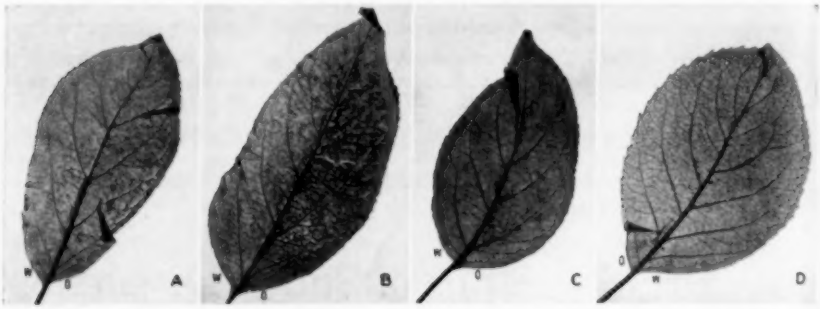

Fig. 1.—Dispersion and relative adhesion of aqueous sulfur suspensions on mature Baldwin apple leaves sprayed as follows: *A*, top surface with *Mouillant* solution until first drop formed; *B*, top surface with *Mouillant* solution until five drops fell from leaf; *C*, top surface with soap solution until five drops fell from leaf; *D*, bottom surface with *Mouillant* solution until first drop formed. o, Original spray deposit; w, deposit left after weathering.

sprayed until five drops of spray fell from the leaf and another series sprayed only until the first drop began to form. All leaves were permitted to dry in the laboratory for 6 hours, then one-half of the sprayed surface was coated with a waterproof lacquer from a hand atomizer to maintain the original coating of sulfur. The lacquer dried in one-half hour and the leaves were then completely submerged for 30 seconds in a bath of distilled water. While this dipping was by no means com-

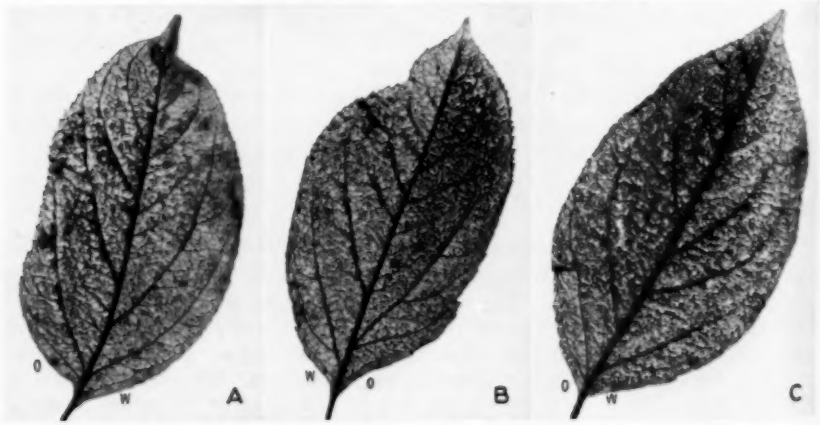

Fig. 2.—Dispersion and relative adhesion of aqueous sulfur suspensions sprayed until they dripped, with *A*, soap solution; *B*, *Areskap* solution; *C*, *Mouillant* solution. o, Original spray deposit; w, deposit left after weathering.

parable to normal weathering it did afford a relatively uniform method of removing the spray residue. After this "artificial weathering" the leaves were again dried and coated with lacquer to preserve any spray materials which survived the "weathering."

The treated leaves were then photographed with Grenz-ray radiation (Sherwood, 1934) as shown in fig. 3. These soft X-rays have the low penetrating power best suited for the production of good radiographs of small, light specimens, such as insects, plant structures, cloth, paper, etc. A special form of X-ray tube is required to produce these rays which must be fitted with an extremely thin window to permit their escape. The voltages applied to the tube range from 2 to 15 kilovolts, which is quite low compared to those used in medical radiography and in radiography of the heavier industrial materials. Photographic plates prepared especially for Grenz-ray radiography were used in all cases. The tube was operated at 8 milliamperes and 8 kilovolts with a target-film distance of 6 inches and an exposure of 5 seconds. A material of relatively low atomic number, such as sulfur, in masses of as small an order as occur in spray residues on foliage does not absorb the penetrating "hard" X-radiation. The "softer" Grenz-ray radiation, however, was almost completely absorbed by individual particles of sulfur, resulting in satisfactory negatives for the study and illustration of sulfur spray residues.

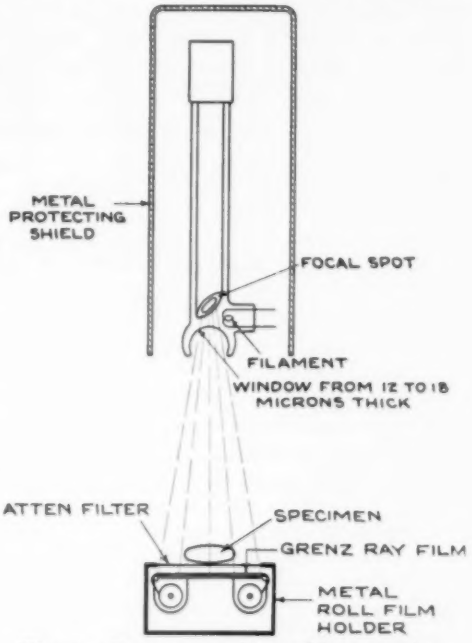

Fig. 3.—Grenz-ray radiographic apparatus.

Of interest is a comparison between the larger amounts of sulfur retained on both lower and upper surfaces of the leaves when sprayed until they dripped, fig. 1, A and B; and a lighter or non-drip spray, figs. 1, D, and 2, C. In the matter of "weathering," heavier initial deposits resulted in larger amounts being retained after dipping. As was expected, the upper surfaces of leaves, figs. 1, B, and 2, C, lost more sulfur through the weathering than the lower surfaces, figs. 1, C, and 2, A. The lower surfaces of the leaves in all cases retained larger amounts of sulfur than the upper surfaces. This was a natural expectancy and is important from the standpoint both of disease and insect control as well as injury to foliage.

Under the conditions of these laboratory tests distinctly larger

amounts of sulfur were deposited on the undersurfaces of leaves sprayed with the *Mouillant* solution, fig. 2. The soap, which wet sulfur fastest and held it in suspension longest, left the lightest deposit of sulfur on the leaves and lost most through the "artificial weathering" process. The marked differences in character of the dispersion with the wetting agents tested is apparent from the photographs.

The factors involved in wetting agents as related to sulfur spray deposits on foliage are too numerous to be evaluated from these preliminary laboratory studies. It is felt, however, that Grenx-ray radiography will provide an accurate and rapid method for studying sulfur spray residues on plant foliage. Further work together with chemical analyses is needed before the possibilities of using the method quantitatively can be intelligently judged.—1-7-37.

Literature Cited

Sherwood, H. F. 1934. Radiography and Clinical Photography 10(4):10–13.

Stickers Used with Calcium and Zinc Arsenates

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Because of the difficulties encountered in the removal of lead residue from fruit, following heavy spraying programs with lead arsenate, there is at present an insistent need for a satisfactory substitute that contains no lead. Such a material, to be of practical value, must be of low cost, readily available, and compatible with established fungicides.

Calcium and zinc arsenates are two materials which in some measure satisfy these requirements, although both have objectionable qualities. Under some conditions both have caused foliage and fruit injury but so also has lead arsenate. Recently certain brands have appeared in which correctives have been incorporated, and with brands not so treated suitable correctives may be added when the spray is mixed. Our tests and observations have indicated that with such correctives, both calcium and zinc arsenates compare favorably with lead arsenate so far as fruit and foliage injury is concerned.

Another objectionable feature of these materials has been their lack of adhesiveness, with the corresponding failure to build up a protective deposit on the fruit. This has led to a search for stickers that might correct this fault.

This paper is a brief report on several stickers tried during the season of 1936.

Data presented in tables 1 and 2 show that when non-lead arsenicals are used, lead residues are eliminated from consideration and that when certain of the stickers are added, the degree of control closely approached that obtained with lead arsenate. The differences in control were greater under conditions of severe infestation.

[1] Journal article 280 n.s., Michigan State College Agricultural Experiment Station.

From these tests and other observations of these materials, when used in commercial orchards, we believe that calcium and zinc arsenates combined with proper correctives and certain stickers will closely approximate lead arsenate as a poison for codling moth under average Michigan conditions.—1-6-37.

Table 1.—Summary of zinc arsenate series, calyx and five cover sprays for all materials. Variety Jonathan; moderate infestation; samples of dropped fruit examined and scored.

Treatment 100 Gallons	Per Cent Uninjured Fruit	Residue Picking Time	
		Lead	Arsenic
Lead arsenate, college schedule	88	.058 .061	.011 .012
Zinc arsenate,* college schedule	79	.002 .003	.008 .008
Zinc arsenate*+1 qt. *Grandpa's Wonder Tar* soap	87	.003 .002	.01 .01
Zinc arsenate*+1 qt. *NOPCO* fish-oil soap	87	.0 .002	.006 .006
Zinc arsenate*+1 qt. *Orthol-K Medium* summer oil	89	.0 .001	.015 .015
Zinc arsenate*+5 oz. *Ortho Dry Spreader*	83	.004 .003	.011 .011
Zinc arsenate*+3 lbs. soybean flour	83	.005 .003	.006 .008
Zinc arsenate*+3 lbs. bill-posters' paste	75	.003 .003	.014 .014

Table 2.—Summary of calcium arsenate series, calyx and five cover sprays for all materials. Varieties Delicious and McIntosh; severe infestation.

Treatment 100 Gallons	Per Cent Uninjured Fruit	Residue Picking Time	
		Lead	Arsenic
Lead arsenate, college schedule	61	.058 .061	.011 .012
Calcium arsenate† + *Grandpa's Wonder Tar* soap	53	.0 .002	.006 .006
Calcium arsenate† + *Orthol-K Medium* summer oil	54	.0 .001	.015 .015
Calcium arsenate† + *Ortho Dry Spreader*	44	.003 .003	.014 .014
Calcium arsenate† + bill-posters' paste	40	.004 .003	.011 .011
Calcium arsenate† + *NOPCO* fish-oil soap	38	.005 .003	.006 .008
Calcium arsenate† + soy bean flour	32	.003 .002	.01 .01

* Corrective for zinc arsenate in 100 gallons: 4 pounds iron sulfate, 4 pounds hydrated lime.

† Corrective for calcium arsenate in 100 gallons: 4 pounds hydrated lime, 4 pounds commercial zinc sulfate.

Adherence and Rate of Settling of Lead Arsenate Dusts

For Autogiro and Airplane Application

Clyde C. Hamilton, *New Jersey Agricultural Experiment Station*,[1] *New Brunswick*

The studies reported in this paper were made for the purpose of modifying lead arsenate dusts so that they could be satisfactorily applied by autogiro or airplane for the control of canker worms or similar leaf-eating insects. The principal problem to be solved was that of improving or modifying the physical properties of the lead arsenate dust so that it would be delivered readily from the container, be broken up into small aggregates of dust particles which would not drift excessively when delivered from the autogiro or airplane, and which would adhere to the foliage.

[1] Paper of the Journal series, New Jersey Agricultural Experiment Station, Department of Entomology.

Arsenical dusts when applied by airplane or autogiro have been used for the control of various insect pests with success. These applications have frequently been followed by the poisoning of honeybees and have the possibility of poisoning other animals due to the dust drifting away from the area for which it was intended. Before this method of applying arsenical dusts can be widely used it would seem imperative that excessive drifting must be prevented. One method of preventing drifting is to apply the arsenicals in a concentrated liquid spray. Francis (1936) gave data on the control of canker worms infesting forested areas by lead arsenate when applied by power sprayers in the usual manner and when applied by autogiro in the form of a concentrated liquid spray and in the form of a dust. Most of his experimental work was done with the concentrated liquid sprays. One test was made with a lead arsenate dust impregnated with sufficient petroleum oil, of about 70 viscosity by the Saybolt test, to make 12 per cent oil in the dust. This dust did not break up satisfactorily when delivered from the autogiro and fell in rather coarse aggregates, some of which formed spots of one-eighth to one-quarter of an inch or more in diameter.

The most satisfactory spray mixture used by Francis for application by the autogiro consisted of lead arsenate 100 pounds, fish oil 5 gallons, petroleum oil $1\frac{1}{2}$ gallons, water $32\frac{1}{2}$ gallons. This formula contains approximately 25 per cent arsenate of lead. The total cost of materials, labor in preparing the spray and hire of the autogiro for applying it was approximately $7.50 per acre, as compared with a total cost of approximately $15 per acre for the ground application with power sprayers. The concentrated lead arsenate spray was mixed with a power sprayer and stored in the tank until used. The lead arsenate and oil dust was prepared by the lead arsenate manufacturer and stored in iron drums until used.

A dust material offers certain advantages over the concentrated liquid spray, such as a greater proportion of lead arsenate in the pay load, and a greater ease in the preparation and handling of the dust, thus making it possible to treat a larger area in a given time.

Adherence of lead arsenate dusts.—Laboratory studies were started the summer of 1935 to determine the effect of different kinds of oils, and different amounts of the same kind of oil on the adherence of lead arsenate dusts to oak foliage. The lead arsenate and oil mixtures were prepared by thoroughly mixing them in a container and brushing the mixture through a 100-mesh screen several times. Five grams of the dust were blown into a box 4 feet square by $6\frac{1}{4}$ feet high and were allowed to settle on the oak foliage for 10 minutes. The oak leaves were washed by placing the branches under spray from a fine nozzle for 15 minutes or until approximately $1\frac{1}{2}$ inches of water had fallen. The spray was about 5 feet above the top of the branches and the branches were placed in three positions during the washing to make the washing more uniform. Three samples of 1 square inch were taken from each leaf, one sample before washing and another sample after each of the first and second washings. Each analysis represents 15 to 20 square inches of leaf. The arsenic trioxide was determined by a modified Gutzeit method. The data are given in table 1.

The data in the last column of table 1 were obtained by taking the average of the per cent arsenic trioxide remaining on the foliage after the first and second washings for the dusts containing 4, 8, and 12 per cent oil. The best adherence of the lead arsenate dust was obtained with fish oil, the second best with *Mineral Seal* oil and the third best with the sperm oil. Very little difference was indicated between the adhering properties of the *Deo-Base* oil, the *Herco* pine oil and the *Solvenol No. 1* pine oil.

Table 1.—Effect of various oils on adherence of lead arsenate dusts to oak foliage. Average of three tests.

Kind and Per Cent of Oil Added to Lead Arsenate	Mgms. As_2O_3 per Square Inch			Per Cent As_2O_3 Adhering		
	Before Washing	After First Washing	After Second Washing	After First Washing	After Second Washing	Av. after First and Second Washings
Lead arsenate—no oil	.089	.021	.011	23.5	12.3	17.9
Fish oil 4%	.078	.037	.031	47.4	39.6	
Fish oil 8%	.070	.041	.031	58.5	44.2	52.5
Fish oil 12%	.111	.083	.056	74.7	50.4	
Sperm oil 4%	.071	.031	.021	43.6	29.2	
Sperm oil 8%	.087	.039	.031	44.8	34.3	36.8
Sperm oil 12%	.104	.047	.025	45.6	23.8	
Mineral Seal oil 4%	.074	.033	.020	45.9	27.	
Mineral Seal oil 8%	.050	.027	.025	53.8	49.8	42.3
Mineral Seal oil 12%	.075	.031	.027	41.3	35.8	
Deo-Base oil 4%	.062	.020	.013	42.7	28.6	
Deo-Base oil 8%	.055	.022	.009	40.	16.3	30.4
Deo-base oil 12%	.051	.018	.010	35.2	19.6	
Herco pine oil 4%	.068	.018	.015	26.4	22.	
Herco pine oil 8%	.079	.027	.016	34.	20.2	30.5
Herco pine oil 12%	.062	.029	.021	46.7	33.8	
Solvenol pine oil 4%	.070	.029	.012	41.4	17.1	
Solvenol pine oil 8%	.064	.024	.015	37.5	23.5	29.3
Solvenol pine oil 12%	.064	.024	.012	37.5	18.6	

A petroleum type oil having the general properties of the *Mineral Seal* oil, *i.e.*, a viscosity of about 70 degrees by the Saybolt test and an unsulfonatable residue of about 92 per cent, was selected for further work. The petroleum oil seemed to be the most practical from a commercial aspect even though the fish oil indicated a better adherence value.

Rate of settling of lead arsenate—petroleum-oil dust mixtures.—Various methods were considered and tried to make the lead arsenate dusts settle out of the air without at the same time causing the dusts to lose too much of their adhering properties, Thinking that the addition of oil to the lead arsenate dust would be likely to form larger aggregates of the dust, tests were undertaken along that line. The results of this series of tests are set forth in table 2.

Five grams of the dust to be tested were blown into the box for each test and allowed to settle for 10 minutes. An average of about five seconds was required to blow the 5 grams of dust into the box. The rate of settling of the dust was determined by exposing 7 by 9-inch glass plates for definite periods of time. This was made possible by means of a shallow galvanized-iron tunnel extending from the door to the back wall of the box. In the center of this tunnel was an opening 8 by 10 inches

through which a glass plate 7 by 9 inches could be exposed. Four glass plates were placed on a galvanized tray sliding in and out of the tunnel. The glass plates were exposed one at a time through the opening in the tunnel. The length of exposure of each glass plate was as follows: plate no. 1 for 15 seconds beginning with the blowing in of the dust; plate no. 2 also for 15 seconds beginning with the end of the first 15 seconds; plate no. 3 for 30 seconds beginning with the end of the second 15 seconds and continuing until the end of the first minute; plate no. 4 for nine minutes beginning with the end of the first minute and continuing until the end

Table 2.—Rate of settling of lead arsenate dusts when mixed with different amounts of a petroleum oil. Average of three tests.

Composition of Dust	Gms. Dust Deposited on Plates During				Gms. Dust on Plates 1 to 4	Gms. Dust on Plate 5	Per Cent of Total Dust Deposited During		
	First 15 Seconds	Next 15 Seconds	Next 30 Seconds	Next 9 Minutes			First 15 Seconds	First 30 Seconds	First 60 Seconds
Lead arsenate—no oil	.009	.009	.011	.043	.072	.066	12.5	25.	40.3
Lead arsenate 95% Petroleum oil *B* 5%	.009	.007	.010	.045	.071	.072	12.6	22.5	36.6
Lead arsenate 90% Petroleum oil *B* 10%	.019	.012	.014	.046	.091	.087	20.8	34.	49.4
Lead arsenate 85% Petroluem oil *B* 15%	.028	.018	.014	.048	.107	.099	26.2	43.	56.1
Lead arsenate 80% Petroleum oil *B* 20%	.032	.015	.014	.033	.094	.101	34.	50.	64.9

of the 10 minute test period. A fifth plate was exposed on top of the galvanized tunnel for the entire 10 minutes to serve as a check for the total amounts deposited on plates 1 to 4. The amount of dust collecting on each 7 by 9-inch glass plate was scraped off with a safety razor blade and weighed on a micro balance.

Table 1 shows that lead arsenate powder mixed with oil increased its speed of fall somewhat in proportion to the amount of oil mixed with it. Studies of the delivery of the lead arsenate–oil dusts showed that 20 per cent oil was about the maximum amount which could be satisfactorily mixed with the lead arsenate. While it is shown by these studies that the speed of fall of the lead arsenate dust particles can be increased by the use of oil there is still too much slow fall of lead arsenate particles, which would be readily driven away by the wind.

Dust mixtures of *Celite*, oil and lead arsenate.—Several methods of producing lead arsenate dusts with rapidly falling qualities were tried. The one finally selected as having the most promise was a mixture of diatomaceous earth, petroleum oil and lead arsenate. The diatomaceous earth was obtained from Johns-Manville Inc., at Manville, N. J., under the trade name *Celite*. This is a diatomaceous earth from Lompoc, Calif., and is of marine origin from marine plankton diatoms. It is very light, having a specific gravity of about 8 pounds per cubic foot of the finely powdered dust, and is extremely porous, having the property of absorbing slightly more than its own weight of oil. A number of different samples of *Celite* were tested in mixtures of *Celite*, petroleum oil and lead

arsenate. The *Celite* finally selected as indicating the best mixtures was designated by Johns-Manville Inc. with the laboratory number of *C-10087*. Dust mixtures made up with this *Celite* gave loose flocculent aggregates when dusted which settled rapidly and adhered well to the glass plates.

The mixture of *Celite*, petroleum oil and lead arsenate was prepared by mixing the oil with the *Celite* dust until it was uniform, then adding the lead arsenate dust and mixing and screening until a uniform fine mixture

Table 3.—The rate of settling of *Celite*, oil and lead arsenate dusts. Average of three tests.

Composition of Dust	Gms. Dust Deposited on Plates During				Gms. Dust on Plates 1 to 4	Gms. Dust on Plate 5	Per Cent of Total Dust Deposited During		
	First 15 Seconds	Next 15 Seconds	Next 30 Seconds	Next 9 Minutes			First 15 Seconds	First 30 Seconds	First 60 Seconds
Lead arsenate	.009	.009	.011	.043	.072	.066	12.5	25.	40.3
C-10087 25% Petroleum oil *B* 15% Lead arsenate 60%	.020	.010	.012	.031	.073	.073	27.4	41.1	57.5
C-10087 25% Petroleum oil *B* 20% Lead arsenate 55%	.030	.017	.013	.017	.077	.078	39.	61.1	78.
C-10087 25% Petroleum oil *B* 25% Lead arsenate 50%	.100	.016	.003	.002	.120	.132	83.3	96.6	99.1
C-10682 25% Petroleum oil *B* 25% Lead arsenate 50%	.062	.013	.004	.003	.083	.078	75.6	91.5	96.3
C-10683 25% Petroleum oil *B* 25% Lead arsenate 50%	.063	.011	.003	.003	.080	.108	78.7	92.5	96.3
C-10433 30% Petroleum oil *B* 20% Lead arsenate 50%	.040	.013	.010	.015	.078	.069	51.3	68.	80.8
C-10604 25% Petroleum oil *B* 25% Lead arsenate 50%	.051	.021	.011	.010	.093	.084	54.8	77.4	89.2

was obtained. Microscopic examinations showed that the fine lead arsenate particles adhered to the outside of the *Celite* particles. The mixture was loose, dusted easily and settled on the glass plates in small flocculent aggregates of the dust. No washing tests to determine the adherence of the mixture were made. However, jarring the glass plates indicated that the dust might have good adherence properties. Table 3 gives the results of tests with several different *Celite* materials.

The data in table 3 show that mixtures of *Celite*, petroleum oil and lead arsenate applied as dusts settle out of the air much faster than lead arsenate alone or then lead arsenate and oil dusts. Furthermore, the greater the amount of petroleum oil in the dust the more rapid the rate of settling. The dust mixture consisting of 25 per cent *Celite 10087*, 25 per cent petroleum oil *B* and 50 per cent lead arsenate settled out very rapidly, giving a deposit on the glass plates of 83.3 per cent during the first 15 seconds, 96.6 per cent during the first 30 seconds and 99.1 per cent during the first minute.

Celite 10682 and *C-10683* were the same as *Celite 10087* except that *C-10682* had been milled once and *C-10683* had been milled twice. The *Celite* particles were smaller than those in *C-10087* and did not have present a small percentage of round somewhat firm particles which were found in *C-10087*. The dust particles or aggregates from the mixtures of *C-10682* and *C-10683*, oil and lead arsenate, were finer than those from mixtures of *C-10087*, oil and lead arsenate.

The *Celite* particles in *C-10433* and *C-10604* were finer than those in *C-10087*, *C-10682* or *C-10683*. This probably accounts for the slightly slower rate of settling of the lead arsenate dusts made with these mixtures.

All of the *Celite*, oil and lead arsenate mixtures reported in table 3 appeared on the glass plates, when examined with the binocular microscope, as loose flocculent aggregates or small particles of *Celite* covered with lead arsenate particles.

Conclusions.—The studies show that mixtures of oil with lead arsenate materially increased the adherence of the lead arsenate to oak foliage. Fish oil gave the best adherence of the oils tested. Adherence of the lead arsenate was directly proportional to the amount of oil mixed with the lead arsenate. The rate of settling of lead arsenate could be increased by adding oil and this rate of settling was directly proportional to the amount of oil added to the lead arsenate. Rate of settling of mixtures of *Celite*, oil and lead arsenate was increased as the amount of oil was increased. Within limits the finer the particles of *Celite* the slower the settling of the dust mixtures. The finer the particles of *Celite* the better the distribution of the dust mixtures on the glass plates. The physical properties of the dust from the standpoint of rate of settling and adherence to glass plates were improved by adding *Celite* to the oil and lead arsenate mixtures.—1-7-37.

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Stickers and Spreaders

Used in Lead Arsenate Sprays for Codling Moth Control[1]

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It is generally agreed among fruit growers that a smooth, continuous film of spray deposit is desirable to allow the fruit to color evenly. Also, where codling moth is a problem, the trend during the past few years has been not only toward a uniform deposit but a heavier and more adhesive residue. A material that imparts these spreading, sticking and deposit-building properties to a spray mixture and at the same time does not

[1] Approved Dec. 21, 1936, by the Director of the New York State Agricultural Experiment Station for publication as Journal paper 180.

complicate residue removal should be an ideal agent to incorporate in the summer sprays that are used for protection against codling moth. This paper gives some of the results of field tests with several types of spreading and adhesive agents used in lead arsenate sprays for combating the codling moth under western New York conditions.

A solid block of 25-year-old McIntosh trees was selected for the tests. The plats were laid out in parallel rows eight trees long by four rows wide and with two plats to the row. The trees were large, well spaced, and the orchard was clean-cultivated. Trees immediately surrounding the experimental block included varieties other than McIntosh that were indifferently sprayed during the summer because of a light crop. As a result, the second brood of worms destroyed most of the fruit on the poorly sprayed trees and continuous protection was required on the experimental plats during the 1936 season.

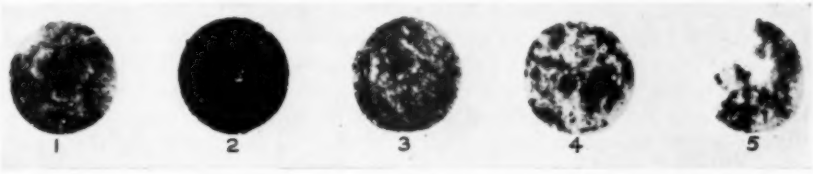

Fig. 1.—Lead sulfide prints of spray residues. (1) Soybean flour 1 lb., lead arsenate 3 lbs. (2) Soybean flour 1 lb., lead arsenate 6 lbs. (3) Skim-milk powder one-half lb., lead arsenate 3 lbs. (4) Lignin pitch 1 lb., lead arsenate 3 lbs. (5) Fish-oil soap 1 qt., lead arsenate 3 lbs.

The summer was abnormally dry and hot. The heat was extreme and no rain fell from late June until the middle of August.

Soybean flour, skim-milk powder, lignin pitch (*Goulac*), and a fish-oil soap (National Oil Products Company soluble fish oil) are the spreaders and adhesives considered in this report. They were used in combination with lead arsenate and hydrated lime in five cover sprays during the period of codling moth activity. Hydrated lime in the mixtures apparently improved the spreading action of the spray in addition to its value as a preventive of possible arsenical injury.

At the time of making the first cover application on the small apples it was practically impossible to secure a smooth, even coating of spray on McIntosh fruit, although the same materials might cover the foliage perfectly. A spotted, blotchy coverage was about the best that could be secured. In July, after the fruit was at least one month old and about 1 inch in diameter, the soybean flour and the skim-milk powder gave film coverage and continued to do so for the remainder of the season. The type of coverage was influenced by the variety. On R. I. Greening the same spray materials produced uniform coverage on the fruit in all cover sprays. On the contrary, the lignin pitch and the fish-oil soap at no time produced a film on the fruit, the residue always being spotted and blotchy in appearance. The accompanying lead sulfide prints, fig. 1, were made from portions of the surface of the fruits and serve to illustrate the type of coverage resulting from the different treatments.

The total crop, both picked fruit and summer drops, from the two

Table 1.—Influence of various stickers and spreaders on codling moth control and spray deposit.

Plat No.	Spray Materials	Rate per 100 Gallons	Worms in 100 Apples	Stings on 100 Apples	Per Cent Efficiency Based on Wormy Fruit	Per Cent Efficiency Based on Total Injury	Spray Residue, Grains per Lb.				Type of Coverage
							Unwashed		Washed (HCl 1.5% at 85° F)		
							arsenic (As_2O_3)	*lead*	*arsenic* (As_2O_3)	*lead*	
1	Lead arsenate Hydrated lime Soybean flour	3 lbs. 2 lbs. 1 lb.	3.2	9.6	97.8	91.5	.085	.192	.003	.007	film
2	Lead arsenate Hydrated lime Soybean flour	6 lbs. 2 lbs. 1 lb.	1.3	5.	99.1	95.7	.12	.264	.006	.014	film
3	Lead arsenate Hydrated lime Skim-milk powder	3 lbs. 2 lbs. ½ lb.	12.1	31.6	91.7	70.2	.077	.165	.003	.009	film
4	Lead arsenate Hydrated lime Lignin pitch (*Goulac*)	3 lbs. 2 lbs. 1 lb.	7.8	18.2	94.7	82.3	.062	.14	.004	.013	blotch
5	Lead arsenate Hydrated lime Fish-oil soap (*NOPCO*)	3 lbs. 2 lbs. 1 qt.	7.8	20.	94.6	81.	.068	.148	.003	.008	blotch
	Check, no cover sprays		*145.5*	*1.*							

middle trees in each plat furnished the figures on control. The list of materials used in the several treatments, codling moth control, type of spray coverage, and amount of residue both before and after washing are given in table 1.

Arsenate of lead used in combination with milk powder resulted in the poorest control of the codling moth, the efficiency rating being 70 per cent. Lead arsenate with lignin pitch and lead arsenate with fish-oil soap were about equally effective, the efficiencies being 82 and 81 per cent respectively. Soybean flour in combination with 3 pounds of lead arsenate in 100 gallons of water left the heaviest residue on the fruit and gave the highest efficiency rating—91 per cent. All residues were easily removed to within the tolerance requirements in a flood washer equipped with rotary underbrushes.

In certain sections of western New York a spray schedule employing 3 pounds of lead arsenate in 100 gallons of water does not provide satisfactory control of the codling moth. Under such conditions the practice has been to increase the amount of lead arsenate to from 4 to 6 pounds, according to the infestation, and the most severe outbreaks have been effectively controlled. A small amount of hydrated lime prevents arsenical injury, and the residue, although as much as 15 times the tolerance, is effectively removed in a flood washer equipped with rotary underbrushes.

Conclusion.—In tests made during the season of 1936 with various spreading and sticking agents used with lead arsenate sprays for combating heavy infestations of the codling moth, soybean flour gave the most satisfactory results. Used at the rate of 1 pound in 100 gallons in combination with lead arsenate and hydrated lime, soybean flour produced a heavy, even coating of spray residue on the fruit, which gave the most effective control and was removed from the picked fruit without difficulty.—1-7-37.

Five Years' Experiments with Lead Arsenate–Summer Oil in Codling Moth Control

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Work with refined lubricating oil as a summer spray for codling moth control at the New Jersey Agricultural Experiment Station previous to 1932 dealt with the use of several highly refined oils of different viscosities. The oils were used as emulsions alone and in combination with organic insecticides in comparison with the standard lead arsenate–lime treatment. In these experiments (Ginsburg 1931a, 1931b; Headlee, Ginsburg & Filmer 1930) several applications of a highly refined oil of 220-seconds viscosity (Saybolt) over a two-year period caused injury both immediate and cumulative. At the same time these experiments

[1] Paper of the Journal series, New Jersey Agricultural Experiment Station, Department of Entomology.

were being carried on, other investigators (Farrar 1936) were working with summer-oil emulsions used alone and in combination with other insecticides such as lead arsenate and nicotine. This work indicated that oils with viscosities between 70 and 100 were less liable to cause foliage and fruit injury than oils of higher viscosities.

By 1932 summer oils had been developed to a point where several commercial concerns were manufacturing and recommending them, usually in combination with lead arsenate or nicotine, for the control of codling moth and other insects. Apple growers began using oil with lead arsenate in the more heavily infested orchards in southern New Jersey to a limited extent in 1931 and increased the use of this combination in 1932, The New Jersey Agricultural Experiment Station issued special recommendations for codling moth control in 1933 for those orchards in southern New Jersey where codling moth had built up to a point where 50 per cent of the fruit was injured at harvest when sprayed with the regular lead arsenate–lime–milk schedule. These special recommendations called for the use of not more than four applications of oil emulsion at .5 to .6 per cent actual oil in the diluted spray at the peaks of first and second-brood egg deposition. Two pounds of lead arsenate powder to 100 gallons water were recommended with the oil. Additional applications of lead arsenate at 3 to 4 pounds per 100 gallons plus hydrated lime were recommended before and after the lead arsenate–oil sprays. An additional provision called for the use of a copper fungicide instead of sulfur in the cover sprays following the calyx application, to avoid injury which usually accompanies the use of oil with or shortly after sulfur applications.

It was felt when these recommendations were first made that the introduction of oil in the lead arsenate schedule for codling moth control increased the possibilities of tree injury, both immediate and cumulative. For this reason it was decided to follow closely the performance of the lead arsenate–oil schedule from year to year to determine its place in the New Jersey apple-spray program. The results set forth in this paper include data and observations taken from a series of plots run in orchards near Moorestown and Glassboro from 1932 to 1936 inclusive.

Experiments at Moorestown.—The block of trees selected for experiment and observation consisted of four rows of Rome Beauty, four rows of Wealthy and three rows of Stayman-Winesap, each row 35 trees long. The three varieties were approximately 18 years old when the work was begun in 1932. The plots used for the different spray treatments during the five-year period consisted of four rows running across the three varieties, which gave 44 trees to each plot. All three varieties were used for observations on injury but only the Romes were used for determining codling moth control. For the first four years of the tests the crop on the Romes averaged 15 to 20 bushels per tree. In 1936 there was only a light crop of about 5 bushels per tree.

In 1932 and 1933 two types of oil were compared, namely, a miscible oil manufactured by the B. G. Pratt Company, known as *Summer Scalecide*, and an oil emulsion known as *Orthol-K*, manufactured by the California Spray Chemical Company. These two oils were used throughout the five-year period. *Scalecide* was used on plot 1 and *Orthol-K* on plot 2

each of the five years, in order to determine any difference in cumulative injury.

From 1934 to 1936 inclusive, plot 3 was sprayed with the standard lead arsenate–lime–milk schedule for comparison with the two oil–lead arsenate plots. This plot had been sprayed in 1932 and 1933 with the oil–lead arsenate schedule. During the same three-year period, plots 4 and 5 were added to test home-made oil emulsions in comparison with the two commercial oils and the standard lead arsenate–lime–milk schedule. Specifications of the oil used and the method of emulsification of these home-made oil emulsions have been published by Ginsburg (1936). Plots 4 and 5 also had been sprayed with a commercial oil plus lead arsenate in 1932 and 1933.

The spray schedule followed on these plots during the five-year period was: oil emulsion plus cresylic acid applied at the delayed-dormant period, followed by two preblossom sprays of liquid lime sulfur and a petal-fall spray of liquid lime sulfur and lead arsenate. A total of seven

Table 1.—Codling moth control with lead arsenate–oil over a five-year period.

Treatment	Per Cent Codling Moth Injury									
	1932		1933		1934		1935		1936	
	Wormy	Total	Wormy	Total	Wormy	Total	Wormy	Total	Wormy	Total
Scalecide+lead arsenate	3	31	17	59	2	12	.2	5	2	19
Orthol–K+lead arsenate	4	26	11	48	1	9	.1	3	2	17
Lime+lead arsenate					2	8	.6	6	3	20
Home-made *A* oil+lead arsenate					1	4	.1	1	2	11
Home-made *B* oil+lead arsenate					1	5	.2	2	1	9

cover sprays followed the petal-fall application, four being applied during first brood and three on second brood. On the oil plots, the first and second cover sprays consisted of lead arsenate 3 pounds and a copper fungicide (Bordeaux or *Coposil*) to 100 gallons. The third, fourth, sixth and seventh cover sprays consisted of lead arsenate 2 pounds, oil at .5 to .6 per cent actual oil in the diluted spray, and spreader to 100 gallons. The fifth cover spray on these oil plots was made up of lead arsenate 3 pounds, lime 6 pounds plus spreader to 100 gallons. The standard lead arsenate plot received seven cover sprays of lead arsenate 3 pounds, lime 6 pounds and dry milk powder one-half pound to 100 gallons, with a sulfur fungicide in the first two cover sprays.

The method followed throughout the period to determine codling moth control was to examine all the fruit on two or three trees, including drops picked up weekly beginning six to eight weeks before harvest. In 1932 a check row was left unsprayed following the calyx, which resulted in 75 per cent of the fruit becoming wormy. After 1932 no unsprayed checks were used. Results were recorded as percentage of fruit stung, wormy and clean.

Spraying throughout the period was by means of a portable rig, the two operators spraying from the ground. In 1932 and 1933 a four-nozzle broom was used to apply the spray. This type of spray delivery equipment resulted in poor coverage in the tops of the trees and consequently poor disease and insect control. From 1934 to 1936 inclusive, a single-nozzle adjustable gun was employed which resulted in more complete coverage and correspondingly better control of codling moth, particularly during first brood.

Table 1 sets forth the codling moth control during the five-year period expressed as percentage of total codling moth injury and as percentage of wormy fruit. An examination of these figures will show that throughout the period the *Orthol-K* oil emulsion gave slightly better control than the miscible oil scalecide both from the standpoint of wormy fruit and stung fruit. It is interesting to note that for the three years the experiments were run, the home-made oil emulsions gave as good or slightly better control than either of the two commercial oils. The data in table 1 show the oil emulsions used with lead arsenate gave a better control of codling moth both from the standpoint of stings and worms than did the lead arsenate–lime for the three-year period.

Table 2.—Codling moth injury on plots sprayed with oil–lead arsenate and lime-lead arsenate: (1) both broods; (2) first brood only.

Treatment	Per Cent Codling Moth Injury			
	1935		1936	
	Wormy	Total	Wormy	Total
(1) *Orthol-K*–lead arsenate	.1	2.6	2.1	16.6
(2) *Orthol-K*–lead arsenate	1.1	3.8	11.1	27.2
(1) Lime–lead arsenate	.6	6.	3.	19.8
(2) Lime–lead arsenate	4.9	11.2	21.6	40.4
(1) Home-made oil–lead arsenate	.1	1.	2.1	10.9
(2) Home-made oil–lead arsenate	1.	2.8	10.4	20.4

It is also interesting to note the importance of thorough coverage regardless of materials used as brought out over the five-year period. Previous to 1932 this orchard was sprayed following the standard lead arsenate–lime schedule. As the trees grew larger and older, codling moth injury became more severe. In 1932 and 1933 a change to what has proved to be a more effective spray combination was made, namely, the use of lead arsenate with oil at the peaks of egg deposition. In spite of this change codling moth injury in 1932 amounted to 25–30 per cent of a full Rome crop, table 1, with an average of 12 worms per tree under chemical bands at harvest. The following year (1933), with the same materials and the same number of applications, codling moth injury on another full Rome crop had doubled and the worms per tree band at harvest had increased from an average of 12 to an average of 50. With the change to a single-nozzle gun in 1934, which resulted in better coverage particularly in the tops on first brood, codling moth injury was reduced to approximately one-fifth of what it was in 1933 and the wormy fruit was further reduced, as shown by the figures for 1934 in table 1. The number of worms per band at harvest in 1934 averaged 1 as compared to 50 in 1933. The low infestation of 1934 was further reduced in 1935 with the continuation of the single-nozzle gun spraying. With the 1936 season exceptionally favorable for codling moth development plus a light crop (20 per cent of normal), total injury increased four or five times of the two previous years. However, compared to 1932 and 1933, satisfactory control of codling moth was obtained in 1936.

Relative control, first-brood spraying only.—During 1935 and again in 1936 a change was made in second-brood treatment in three of the

plots which it was thought would bring out more clearly the difference between the oil–lead arsenate schedules and the lime–lead arsenate schedule. The *Orthol-K*–lead arsenate plot, the lime–lead arsenate plot and the home-made *A* oil–lead arsenate plot were each divided in half at the end of first-brood spraying. One-half of each plot received the usual three second-brood sprays and the other half received no second-brood sprays. The usual counts of all the fruit including drops on two trees in each plot were made at harvest. The results are set forth in table 2.

The data in table 2 show a superiority of the oil–lead arsenate treatments over the lime–lead arsenate treatment. In 1935 the two oil–lead arsenate plots, sprayed both broods, had .1 per cent wormy fruit compared to .6 per cent on the lime–lead arsenate-sprayed plot. The sections

Table 3.—Control of codling moth at Glassboro on Stayman plots sprayed with lead arsenate–oil compared to plots sprayed with lead arsenate–lime–milk.

Treatment	Per Cent Clean Apples			
	1933	1934	1935	1936
Orthol-K–lead arsenate	13.3	40.2	48.3	69.2
Lime–lead arsenate–milk	10.9	37.9	12.4	44.4

of these plots receiving first-brood sprays only showed roughly 1 per cent wormy fruit on the two oil–lead arsenate plots and 5 per cent wormy on the lime–lead arsenate plot. The total injury figures for 1935 show the same trend.

The 1936 figures show 2 per cent wormy fruit for the two oil–lead arsenate plots sprayed both broods compared with 3 per cent wormy fruit on the lime–lead arsenate plot sprayed both broods. The section of these plots receiving first-brood sprays only shows twice as much wormy fruit on the lime–lead arsenate plot as was found on the oil–lead arsenate plots. The total injury figures for 1936 show the same trend as the figures for wormy fruit.

Experiments at Glassboro.—A series of block tests have been run in an orchard heavily infested with codling moth at Glassboro from 1934 to 1936 inclusive, in which various fixed-nicotine formulae were tested in comparison with the standard lead arsenate–lime and the lead arsenate–oil schedules. Part of the data from this series of experiments has been published in detail elsewhere (Driggers & Pepper 1934, 1935; Driggers 1936). Table 3 sets forth the percentages of clean fruit on Stayman for the four-year period on plots sprayed with lead arsenate–oil compared to plots sprayed with lead arsenate–lime–milk. In each of the four years the data show the superiority of the oil–lead arsenate over the lime–lead arsenate.

Observation on injury.—Frequent observations were made on injury on the three varieties under test at Moorestown and on several varieties at Glassboro during the five-year period. No accumulative injury has been observed to date on the oil–lead arsenate plots either at Moorestown or Glassboro. The reduction in crop in 1936 to approximately 20 per cent of the crop of previous years occurred on the standard lead arsenate–

lime–milk plot as well as on the lead arsenate–oil plots. Frost damage at blooming time in the spring of 1936 was responsible in part for the light yield that year. Limiting the strength of oil to .5–.6 per cent actual oil in the diluted spray and limiting the total applications to four per season have apparently avoided cumulative injury to date, at least on the varieties tested.

More or less arsenical injury has appeared each season on all the plots and in some seasons the injury with the oil–lead arsenate sprays without lime appeared to be greater than the injury observed on the plots sprayed with lead arsenate–lime continuously. Slight to moderate copper injury on the fruit has been observed each season on the oil–lead arsenate plots which received a copper fungicide in the early cover sprays. This type of injury was absent on the standard lead arsenate–lime plots which received wettable sulfur in the early cover sprays. On the other hand, severe sulfur burn on the fruit was observed on the lead arsenate–lime plot two seasons when temperatures around 100° F prevailed during June.

During one season (1934) a severe leaf drop occurred in June on the Stayman variety at Moorestown and to a lesser extent at Glassboro. About a week after the first oil–lead arsenate application on first brood in 1934 approximately 25 per cent of the leaves turned yellow and dropped. This injury occurred on all the oil plots at Moorestown and Glassboro on the Stayman and old-fashioned Winesap varieties but was negligible on the Wealthy and Rome varieties. No such injury occurred on the Staymans in the lead arsenate–lime–milk plots. The cause of the injury that year disappeared after the first oil application because three subsequent oil–lead arsenate applications were made without increasing the leaf drop. It is believed that the severe leaf drop on the Staymans was due to a combination of tree condition and sulfur residue left from previous sprays. The Stayman variety at Moorestown in the early summer of 1934 was decidedly over-vegetative. This condition plus the sulfur residue left from the calyx spray may have resulted in an oil–sulfur injury of severe proportions that particular season.

Summary and conclusions.—A spray schedule of oil and lead arsenate for codling moth control was compared to a spray schedule of lead arsenate–lime–milk on several varieties over a five-year period at Moorestown and Glassboro. No cumulative injury from the use of the oil has been observed to date. More foliage injury of a seasonal nature was observed on oil–lead arsenate-sprayed plots than on lime–lead arsenate-sprayed plots. This injury was not sufficiently pronounced, however, to vitiate the improved codling moth control observed. The use of oil with lead arsenate at the peaks of egg deposition improved the codling moth control over a schedule of lead arsenate–lime–milk. An oil emulsion used with lead arsenate gave slightly better control than a miscible oil used with lead arsenate. Three years of tests with home-made oil emulsions used with lead arsenate gave control of codling moth slightly better than that obtained with a commercial oil emulsion and lead arsenate with no difference observable in fruit or foliage injury. The results show that summer oils have a place in the apple spray program in the heavily infested orchards in the two-brood area of southern New Jersey.—1-22-37.

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Effect of Certain Codling Moth Spray Schedules on Other Orchard Insects

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Throughout Ohio particular orchard insect problems are generally less severe than in many other states. To offset this good fortune, however, several different fruit insects are always present and may at any time increase to the point of becoming serious menaces to economic apple production. During the last 10 years insects such as the apple flea weevil, *Orchestes pallicornis* Say, the plum curculio, *Conotrachelus nenuphar* (Hbst.), the apple maggot, *Rhagoletis pomonella* (Walsh), and different species of apple aphids, leafhoppers and scales have at times been serious pests in Ohio orchards. In addition, the European red mite, *Paratetranychus pilosus* (C. & F.), has taken heavy toll in certain seasons. The codling moth is, of course, our major problem in the orchard but in planning for its control the other insect pests cannot be forgotten. Not only must all possible insect problems be remembered, but provisions must be made also for the inclusion of suitable fungicides. Without them the Ohio apple crop would suffer in any season, and in some years would be wiped out almost entirely. Varying amounts and types of fungicides may be used according to location and variety, but for safety some fungicide should always be used in the calyx and early cover sprays. For example, in 1934 and 1936 the variety Courtland, after receiving fungicides up to and including the calyx, came through the season with slight scab injury but in 1935 more than 60 per cent of the fruit was injured by scab, following the same schedule.

Insect problems other than codling moth must be considered in much the same light as the disease problems; in other words, any spray schedule must be so composed that it will be effective in the control of all pests likely to become serious in any given season.

In reviewing Ohio work prior to 1936 with reference to the effects of various spray materials upon different orchard insects several facts have been noted. These, without the inclusion of the supporting data, may be summarized as follows: (1) Non-lead arsenicals, such as calcium, zinc, and manganese arsenates, have controlled the apple maggot and may be used against plum curculio. (2) Summer oil sprays have shown little effect on apple maggot unless preceded by several applications of an arsenical; also there was some evidence of more extensive fall feeding by curculio on such plots. Two or more applications of summer oil, however, have greatly assisted in the control of the scurfy scale, *Chionaspis furfura* Fitch. (3) Sprays containing nicotine in different forms were not successful against apple maggot. (4) Flourine compounds controlled flea weevil and plum curculio. There has been no opportunity to test them against apple maggot.

Table 1.—Spray schedule, 1936.

Schedule No.	Materials*	Spray No. 3	4A	4B	4C	5A
		Calyx May 14	First Brood Covers June 4	June 15	June 29	Midsummer July 23–24
7A	Lead arsenate	3 lb.	2 lb.	2 lb.		2 lb.
	Liquid lime sulfur	1 gal.	1 gal.	1 gal.		2 lb. Dry
	Miscible sulfur	5 lb.	4 lb.	4 lb.		
	Lime	3 lb.	3 lb.	3 lb.		4 lb.
8A	*Ortho Nicotine*	4 lb.	4 lb.	4 lb.	4 lb	4 lb.
	Coposil	2 lb.	2 lb.			
	Orthol Ready Mix Oil	2 qt.	2 qt.	2 qt.	2 qt.	2 qt.
9A	Phenothiazine (du Pont)	3 lb.	3 lb.	3 lb.	3 lb.	3 lb.
10A	Phenothiazine (du Pont)	3 lb.	3 lb.	3 lb.	3 lb.	3 lb.
	Flotation sulfur	5 lb.	5 lb.	5 lb.	5 lb.	5 lb.
	Grasselli SS-3	1½ cc.	1½ cc.	1½ cc.	1½ cc.	1½ cc.
	Gelatin†	200 cc.	200 cc.	200 cc.	200 cc.	200 cc.
11A	Lead arsenate	3 lb.	2 lb.	2 lb.	2 lb.	2 lb.
	Flotation sulfur	5 lb.	5 lb.	5 lb.	5 lb.	5 lb.
	Lime	3 lb.	2 lb.	2 lb	2 lb.	2 lb.
	Grasselli SS-3	1½ cc.	1½ cc.	1½ cc.	1½ cc.	1½ cc.
	Gelatin†	200 cc.	200 cc.	200 cc.	200 cc.	200 cc.

* Formulae diluted with 100 gallons of water. † Five per cent solution.

During the season of 1936 the experimental codling moth program included the use of phenothiazine throughout the season on several varieties of apple. The material was applied alone, with a wetting agent incorporated by the manufacturer, with soybean flour as a wetting agent, and in combination with flotation sulfur as a fungicide. Also, *Ortho Nicotine*, with .5 per cent *Orthol Ready Mix Oil*, and with *Coposil* as a fungicide, was used throughout the season on the same varieties. All comparisons were made against lead arsenate, which was used in amounts 33.33 per cent less than recommended in the standard schedule. The work was done at Wooster in a young orchard 11 years of age; all the trees were vigorous and producing at least a fair amoung of fruit. Standard practices in culture, pruning, fertilization and spraying have always been observed in this orchard, and it may be considered typical for northeastern Ohio. Eight standard varieties (Ben Davis, Jonathan, Courtland, King David, McIntosh, Wealthy, Grimes and Golden Delicious) were included in each treatment. Single-tree plots were used, with two

to eight replicates in every variety. All tables are summaries for the variety indicated.

Table 1 shows the spray schedule for 1936.

The first pest on which records were secured was the European red mite. Damage was noted in early midsummer, and on July 15 counts of

Table 2.—Mites and eggs per leaf.

Schedule No.*	Varieties					Mean
	Ben Davis	Court-land	King David	McIntosh	Grimes	
7A	3	6	9	6	21	9
8A	7	13	12	6	15	10
9A	41	40	40	42	33	39
10A	42	39	30	43	42	39
11A	16	33	29	39	24	29

* See table 1 for details of materials used, dates and numbers of applications.

mite populations on leaves were started. These were interrupted from time to time by other work and were not completed until August 1. This interval of time may account for the difference in mite numbers recorded, but as the data for each variety of apple were completed at one time it is felt that such differences are explicable due to the above factors. A summary of all leaf population counts, expressed as mites per leaf and based on a count of 50 leaves per tree of each variety in each treatment, is given in table 2.

A study of table 2 indicates quite definitely that phenothiazine was not effective in the control of red mite, and that flotation sulfur, of the type used, was not as successful as liquid lime sulfur or the .5 per cent *Ready Mix Oil* used on plot 8 A.

Table 3.—Per cent of terminals infested by green aphis.

Schedule No.*	Varieties							Mean
	Ben Davis	Jona-than	Court-land	McIn-tosh	Wealthy	Grimes	Golden Delicious	
7A	10	13	60	21	3	7	30	20
8A	2	0	6	5	6	7	2	4
9A	2	4	9	10	6	3	0	5

* See table 1 for details of materials used, dates and numbers of applications.

A light outbreak of green apple aphis developed in the orchard during June and early July. Counts of infested and uninfested terminals were made on the different treatments and varieties and the results in terms of percentages are shown in table 3.

Although results vary greatly among varieties, it is evident that measurable control was obtained with oil–*Ortho Nicotine* and also with phenothiazine. Laboratory tests with the latter show that its killing or irritating action is very slow. Few aphids die by the end of a 24-hour period but in four or five days many populous colonies will be greatly

reduced. The reasons for this have not been found, hence an opportunity for further interesting work is open.

The infestation of apple maggot throughout the orchard was rather light. Counts made by dissecting drop fruits showed little differences among materials, but a few more maggots were found on the oil–ortho nicotine plots. In an adjacent orchard, however, where all the trees were sprayed either with lead arsenate or with phenothiazine, the average per cents of maggot-injured drop fruit were 5 and 15 per cent respectively. The labor involved in dissection limited the number of apples per sample, however, and it is entirely possible that the difference is not significant.

Table 4.—Per cent of fruits injured by curculio.

Schedule No.*	Varieties								Mean
	Ben Davis	Court-land	Jona-than	King David	McIn-tosh	Wealthy	Grimes	Golden Delicious	
7A	21	4	3	1	8	12	6	2	7
8A	74	16	20	64		22	34	20	36
9A	55	13	20		17	57	40	9	30
10A	78	19	10	47	27	55	40	21	37
11A	59	23	11	7		12	7	7	18

* See table 1 for details of materials used, dates and numbers of applications.

Several colonies of the yellow-necked caterpillar, *Datana ministra* (Drury), were noted feeding on trees where spraying had been discontinued early in the season. No mature colonies were observed on any of the plots in this series of comparisons. On one tree sprayed with phenothiazine several very young colonies, with all the larvae dead, were found. Apparently, feeding had lasted for a few hours only.

Plum curculio is second in importance to codling moth as a persistent and widespread pest in Ohio apple orchards, and any schedule that fails to control it is virtually eliminated from horticultural use. Fluctuations in curculio damage occur from year to year but usually these variations are less noticeable than with other orchard insects. The results in controlling plum curculio, as shown in table 4, are therefore, quite important, especially to Ohio growers.

Material 11 A was applied on trees which, for the most part, adjoined an overgrown fencerow quite favorable for curculio hibernation. It is thought that this factor explains the higher percentage of injured fruit found on these plots.

Although there is considerable variability in the data of table 4, the general trend is quite definite. Phenothiazine and oil–nicotine when used throughout the season did not control curculio.

Since lead arrsenate in the calyx or other early season sprays is the recognized control for curculio, split schedules of the experimental materials with lead arsenate in the first application (calyx) were found quite satisfactory in curculio control.

The experiment was planned primarily to test all-season schedules of phenothiazine and oil–*Ortho Nicotine* against codling moth. Fortunately

a rather heavy infestation developed and the results, expressed in terms of worms per 100 apples, are given in table 5.

An inspection of table 5 shows that phenothiazine and oil–*Ortho Nicotine* were not effective. Apparently the weak spot in the all-season schedule of these materials is the calyx spray, since counts show that a very

Table 5.—Codling moth larvae per 100 apples.

Schedule No.*	Varieties								Mean
	Ben Davis	Court-land	Jona-than	King David	McIn-tosh	Wealthy	Grimes	Golden Delicious	
7A	52	36	7	12	4	1	3	9	15
8A	82	39	18	29		6	7	15	28
9A	84	52	32		15	6	24	30	35
10A	82	43	42	37	20	3	20	30	34
11A	27	23	9	17		10	7	5	14

* See table 1 for details of materials used, dates and numbers of applications.

high proportion of the larvae entered through the calyx. Much better results were obtained where the schedules were split and lead arsenate was used in the early sprays.

Summary.—All-season schedules of phenothiazine failed to control satisfactorily red mite, curculio and codling moth but reduced the population of green apple aphis.

Oil–*Ortho Nicotine* controlled green apple aphis and red mite, but injury by curculio and codling moth was severe.

When lead arsenate was used in the calyx and followed by either phenothiazine or oil–*Ortho Nicotine* schedules, control of codling moth, and particularly plum curculio, was greatly improved over the all-season use of these materials.—3-18-37.

Tests with Bait and Light to Trap Codling Moth

H. N. Worthley and J. E. Nicholas, *Pennsylvania Agricultural Experiment Station*,[1] *State College*

According to Parrott & Collins (1935), traps comprising a light source surrounded by a cylindrical electrocuting grid have shown promise of trapping economic numbers of codling moth adults, *Carpocapsa pomonella* L. However, the initial cost of such devices is high, and although they may be seen occasionally in heavily populated packing houses and crate storages, their use in orchards has been confined to experimental installations. It was with the thought of developing a cheaper trap of similar effectiveness that this study was started in 1934.

Methods.—A double line of No. 10 W.P. wire was strung from tree to tree in a rough circle about the center of a block of unsprayed, mature

[1] Authorized Dec. 14, 1936, for publication as paper 749 in the Journal series, Agricultural Experiment Station.

apple trees, at a height of about 12 feet above the ground. Porcelain insulators screwed to the main branches supported the wires. Soldered and taped leads were taken to a pigtail socket fastened to the trunk of every second tree. Twelve trees were thus wired. The traps were hung by means of rope and pulleys at the highest possible point in each of these trees, and were supplied with electric current through No. 16 *Tyrex* cord fastened to the pigtail sockets by plug-in connections. The 110-volt circuit was controlled by a time switch which was set to turn the current on at 7 p.m. and off at 7 a.m. Thermostatic and photoelectric controls were not available.

Table 1.—Adult codling moths trapped, State College, Pa., May 20 to August 3, 1934.

Trap No.	Type of Trap	All Moths	Female Moths	Per Cent Female	Per Cent of Season Total	
					All Moths	Female Moths
1	75-watt bulb enclosed by electrocuting grid	345	128	37.1	46.4	41.
2	Reflector over 6-inch diameter can, bait, no light	28	20	71.4	3.8	6.4
3	As No. 2, plus 75-watt bulb	169	73	43.2	22.7	23.4
4	Six-inch diameter can, bait, no reflector no light	13	6	46.1	1.7	1.9
5	Reflector over 6-inch diameter can, water, light	133	52	39.1	17.9	16.7
6	Six-inch diameter can, bait plus *Anethol*, no reflector, no light	55	33	60.	7.4	10.6
	Season total	*743*	*312*	*42.*		

During each period of operation six types of traps were employed, the series being repeated to give a total of 12 traps. Except in 1936, lighted and unlighted traps alternated, thus providing a light source only in every fourth tree. The traps were lowered, examined, and moved one tree forward in the circle each morning, and so moved completely around the circle every 12 days.

The light source employed was the 75-watt, inside-frosted *Mazda* bulb, and the bait used consisted of 1 part *Brer Rabbit Green Label* molasses to 9 parts water. Baits were replenished and changed as frequently as necessary to provide continuous alcoholic fermentation. In one test 1 cc. of *Anethol* was added to the 3 quarts of bait in each trap as an attrahent, and in one series water alone replaced the bait in some traps.

Studies in 1934.—From May 20 to August 3, 1934, the initial experiment compared the following types of traps:

(1) An *Insekiller* trap manufactured by the Folmer-Chapin Corporation, Rochester, N. Y.[2] This is essentially a heavy reflector housing a bulb socket and a transformer that supplies current of high voltage and low amperage to a cylindrical grid suspended from the reflector. A wire basket catches insects electrocuted in attempting to approach the light between the bars of the grid. Traps of this type retail for about $15 up.

(2) A No. 10 preserving can 6 inches in diameter, painted with aluminum paint, and suspended below a 14-inch aluminum reflector. This trap was not lighted, but was kept supplied with bait.

[2] Now the Folmer Electracide Corporation.

(3) As No. 2, but lighted.
(4) A bait can as in No 2, without reflector or light.
(5) As No. 3, with water instead of bait.
(6) As No. 4, with 1 cc. of *Anethol* per trap.

Table 2.—Adult codling moths trapped, State College, Pa., August 4 to September 9, 1934.

Trap No.	Type of Trap	All Moths	Female Moths	Per Cent Female	Per Cent of Season Total	
					All Moths	Female Moths
1	75-watt bulb enclosed by electrocuting grid	47	20	42.6	17.8	16.1
2	Reflector over 12-inch diameter pan, bait, no light	4	2	50.	1.5	1.6
3	As No. 2, plus 75-watt bulb	80	38	47.5	30.3	30.6
4	Six-inch diameter can, bait, no reflector, no light	7	7	100.	2.7	5.6
5	Reflector over 12-inch diameter pan, water, light	116	53	45.7	43.9	42.7
6	Twelve-inch diameter pan, bait, no reflector, no light	10	4	40.	3.8	3.2
	Season total	*264*	*124*	47.		

Records from the operation of this set-up, as given in table 1, show that lighted traps caught far more moths than unlighted traps. They also caught more females, though in smaller proportion than the unlighted traps.

Bait was of additional value in a lighted trap, as shown by Nos. 3 and 5, table 1. Addition of *Anethol* in No. 6 markedly increased the catch as compared with No. 4, but not to a point comparable with that in lighted traps.

Table 3.—Adult codling moths trapped, State College, Pa., May 23 to September 1, 1935.

Trap No.	Type of Trap	All Moths	Female Moths	Per Cent Female	Per Cent of Season Total	
					All Moths	Female Moths
1	75-watt bulb enclosed by electrocuting grid	291	133	45.7	20.6	21.
2	Reflector and baffles over 12-inch pan, bait, no light	55	30	54.5	4.	4.7
3	As No. 2, plus 75-watt bulb	451	208	46.1	32.	32.8
4	Six inch can, bait, no reflector, no light	33	18	54.5	2.3	2.8
5	Reflector over 12-inch pan, no baffles, bait, light	532	211	39.7	37.7	33.3
6	As No. 5, without light	48	34	70.8	3.4	5.3
	Season total	*1410*	*634*	45.		

Moth catch in the lighted bait can traps, No. 2, was encouraging, although lower than in the electrocuting traps, No. 1. Moth catches in the latter cannot be determined with accuracy, for some individuals killed are burned beyond recognition.

In hope of improving the bait traps by increasing the area of the trapping surface, 12-inch aluminum-painted cake tins were substituted for the 6-inch bait cans in some of the traps, beginning on August 4. The catches in this series are shown in table 2.

Increase in the area of the liquid surface under the lights resulted in larger moth catches than in the electrocuting traps. The total moth catch during the period represented in table 2 was too small to allow definite conclusions.

Studies in 1935.—Traps were operated from May 23 to September 1 in 1935. The 6-inch bait can without light or reflector, as ordinarily used to trap moths in the timing of spray applications, was compared with the electrocuting light trap, the 12-inch bait pan under a light and reflector, and a modification of this last type of trap to include vertical baffles placed at right angles to each other between the light and the

Table 4.—Adult codling moths trapped, State College, Pa., June 6 to September 9, 1936.

Trap No.	Type of Trap	All Moths	Female Moths	Per Cent Female	Per Cent of Season Total	
					All Moths	Female Moths
1	75-watt bulb enclosed by electrocuting grid	212	95	44.8	13.6	14.3
2	75-watt bulb in unpainted trapping globe	120	41	34.2	7.7	6.2
3	As No. 2, with globe painted black at top and bottom	306	86	28.1	19.7	12.9
4	As No. 2, with globe painted to give light only through slots	198	89	44.9	12.7	13.4
5	Reflector and baffles over 12-inch pan, bait, light	663	310	46.8	42.6	46.5
6	Six-inch can, bait, no reflector, no light	57	45	78.9	3.7	6.7
	Season total	*1556*	*666*	*42.8*		

bait surface, and fastened to the wires by which the pan was suspended from the reflector. This trap was assembled by a local tinsmith at a cost of $1.50. The records for 1935 are given in table 3.

Examination of table 3 shows that the results obtained in 1934 were repeated in 1935. The simple bait can was the least effective trap. All unlighted traps caught relatively few moths, though a larger proportion of females than the lighted traps. Many more moths were recovered from the lighted 12-inch bait pans than from the electrocuting traps. The addition of baffles above the 12-inch bait pans reduced the total catch of moths, but appeared to have no effect upon the number of females trapped.

Studies in 1936.—Traps were operated throughout the season, and the bait cans, electrocuting traps and lighted bait pans with baffles were included as in 1935. In addition, the merits of a patented insect-trapping light globe were investigated. This device has been figured and described by Tietz (1936). It is a flattened cylinder of opal glass 8.5 inches in diameter, with three funnels molded into its circumference at equidistant points. Each funnel points toward the light source within, and is ground off at the apex to form an entrance slot 1.5 by .5 inches to admit insects attracted by the light. Two of these globes were painted black to emit light only from the slots, two were painted at the top and bottom to leave a lighted central band about the funnels, and two were used unpainted.

The records for 1936 appear in table 4. Again the lighted 12-inch bait pans excelled, yielding over three times as many moths as the electrocut-

ing traps. The trapping light globes were less effective, but the records are interesting. They caught the fewest moths when used unpainted, with light emanating from the whole surface of the globe (No. 2). They caught the most moths when painted to show a band of light about the funnels (No. 3), but the catch was predominantly male. The globes painted so that light showed only through the slots (No. 4) caught fewer moths than No. 3, but more females; in fact 93 per cent as many as the electrocuting type of trap.

Discussion.—The effectiveness of bait traps may be greatly increased by suspending them beneath 75-watt lights, as revealed by tests conducted in 1934 and 1935. Table 5 summarizes the results with those bait traps that were operated both with and without light.

Table 5.—Effect of light on codling moth catch in bait traps, State College, Pa., 1934–35.

	All Comparable Tests		
	Without Light	Light Added	Ratio
All moths	87	700	1:8
Female moths	52	319	1:6.1
Per cent female	60	46	

Table 6.—Codling moths recovered from traps of the electrocuting and the lighted bait pan types, State College, Pa., 1934–36.

	All Comparable Tests		
	75-watt Bulb in Electrocuting Grid	75-watt Bulb over 12-inch Diameter Bait Pan	Ratio
All moths	550	1194	1:2.17
Female moths	248	556	1:2.26
Per cent female	45	46	

Results obtained in three seasons appear to show that a trap costing $1.50 to make, and consisting of a light and reflector suspended above molasses-water bait in a pan 12 inches in diameter, is more effective in killing codling moth adults than an electrocuting light trap that sells for about $15. Table 6 summarizes the results achieved with these two types of traps.

As already indicated, comparisons between the electrocuting trap and other devices may be misleading, for many insects killed by the former are burned beyond recognition. However, close examination of the catches in these traps makes it appear improbable that half of the moths are thus destroyed, a result that would show these two types of trap to be equally effective.

Employed in commercial orchards to reduce codling moth populations, the combination bait and light trap would be somewhat more expensive to operate than the electrocuting trap. The latter is automatic, while the former must be cleaned frequently and recharged with bait about every 10 days. However, the cost of bait and labor would scarcely equal interest on the extra investment in the electrocuting traps.

Preliminary tests with the trapping light globes are encouraging, and means of increasing their effectiveness should be sought. The use of *Anethol* as an attrahent with bait in 1934 increased the catch of female moths more than five times (table 1, Nos. 4 and 6). Several other attrahents tested by Frost (1935) on the Oriental fruit moth deserve consideration. It may be possible to increase the effectiveness of the trapping globe by providing it with a capacious metal base containing an attrahent to be slowly driven off by the heat of the lamp. Such a trap would

need less frequent attention than the type employing a liquid surface as the trapping device. Further study is contemplated.—4-29-37.

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Effects of Light Traps on a Codling Moth Infestation

A Consideration of Four Years' Data

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This paper has been prepared to assemble and compare the data for four consecutive years on codling moth injury and population in an apple orchard equipped with light traps. The experiments were first undertaken in 1933 in a Rome Beauty orchard which was then approximately 35 years old. Trees of other varieties had been interplanted with the Rome Beauty trees at regular intervals, but for the sake of uniformity only the data from the Rome Beauty variety are considered here. In the "lighted areas" a light trap of the electrocuting type was installed in every tree. The light source was a 75-watt type A *Mazda* lamp, with mercury vapor tubes and sun lamps in certain trees for comparison.

Since during the first season check trees and trees receiving one cover spray of lead arsenate were found to be inferior to trees with light alone, with respect to codling moth infestation, such plats were omitted in subsequent years. For comparisons, therefore, the trees are distributed among the following plats:

(1) Light traps; no lead arsenate
(2) Light traps; two cover sprays
(3) Light traps; three cover sprays
(4) Light traps; four cover sprays
(5) Two cover sprays; no light traps
(6) Three cover sprays; no light traps
(7) Four cover sprays; no light traps

As a result of the severe winter of 1933–34, a number of trees and parts of trees died during the ensuing years. This necessitated the removal of

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal paper 179, Dec. 21, 1936. The experiments have been carried on at the New York station as a cooperative project involving the experiment station, Cornell University, and the United States Bureau of Entomology and Plant Quarantine, with the assistance of the Empire State Gas and Electric Association.

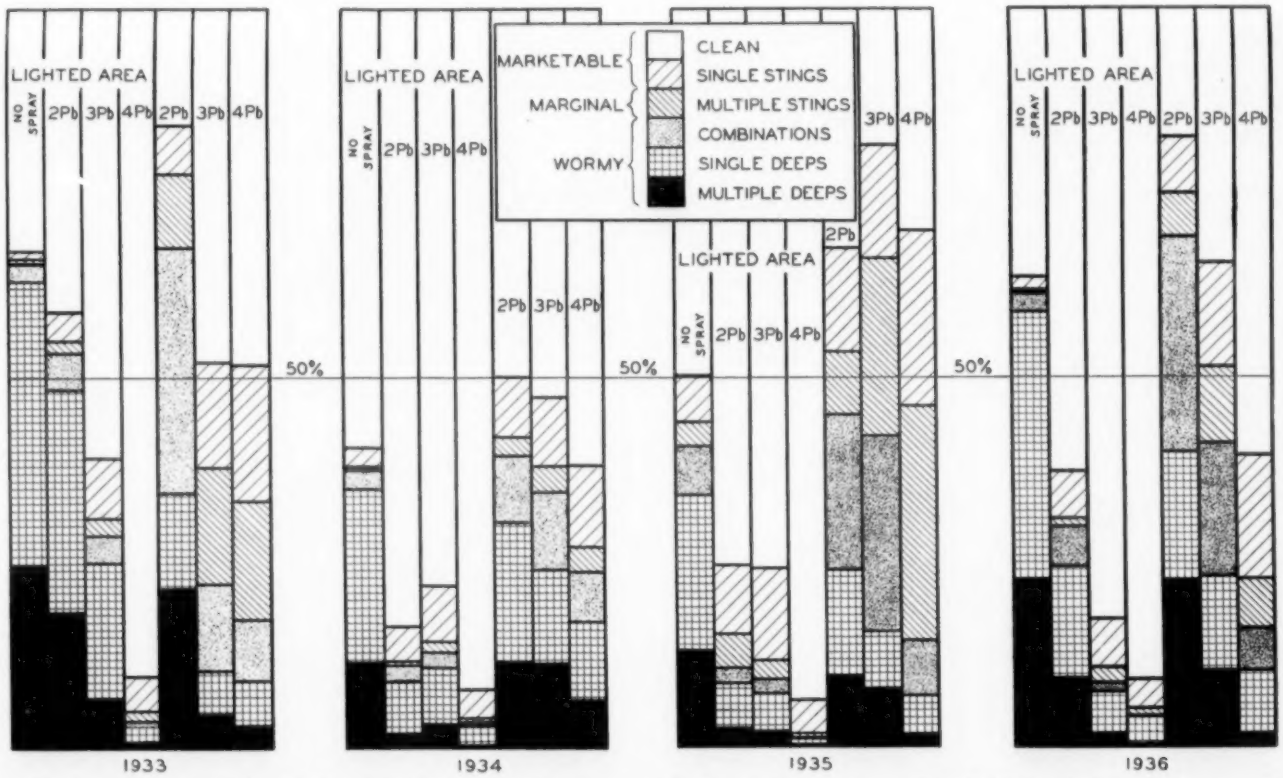

Fig. 1.—Annual records of codling moth injury. Each bar represents the total crop from a plat, divided as indicated. A numeral placed before the symbol *Pb* designates the number of lead arsenate cover sprays that were applied.

certain trees and considerable pruning of others, so that some plats which were already established had an insufficient number of trees or apples. There are, therefore, several instances where the statistical foundations for the data used might be considered inadequate. The figures in table 1 afford a basis for judging the relative reliability of the data from each plat each year.

For clarity and brevity the data are presented here in the form of charts. The basis of the computations used in figs. 1 and 2 was the examination of the total crop, including the drops, of each tree. Each bar expresses the condition of the total crop of a given plat, distributed on a percentage basis, among the following categories: (1) *multiple deeps*,

Table 1.—Composition and yields of plats.

Plat Treatment	No. Trees				Average No. Apples per Tree			
	1933	1934	1935	1936	1933	1934	1935	1936
Lights only	8	10	10	7	2858	2469	1046	1126
Lights, two lead	2	5	5	3	2382	2568	1007	680
Lights, three lead	2	2	2	3	2279	2383	2005	733
Lights, four lead	1	1	1	3	5049	3042	2721	1235
Two lead only	1	4	4	4	3358	3791	964	1459
Three lead only	1	6	6	3	3588	3916	1082	1679
Four lead only	6	6	5	5	3440	3881	1512	1494

apples bearing more than one "deep wormhole" but no stings; (2) *single deeps*, apples bearing one wormhole but no stings; (3) *combinations*, apples bearing both wormholes and stings; (4) *multiple stings*, apples bearing more than one sting but no wormholes; (5) *single stings*, apples bearing one sting but no wormholes; (6) *clean apples*, apples free from codling moth injury. These categories may be grouped into the three classes indicated in the key, namely wormy fruit, marginal fruit, and marketable fruit.

In fig. 1, the percentages were calculated from the total figures for each plat. Data from the four years as represented in fig. 1 are summarized in fig. 2 on the basis of the "unweighted" mean and on the basis of the "weighted" mean; that is, the points in fig. 2a were determined by the averages of the yearly percentages while the percentages plotted in fig. 2b were obtained from the actual sum total figures of each category for the four years. Figure 3 is a reproduction of the "wormy" segments of the bars in fig. 2b to which have been added other data as follows: (1) the number per 100 apples of caterpillars found under bands, indicated by broad black bands, and (2) the number of wormholes per 100 apples in each plat, indicated by narrow black bars.

Consistency of the data from year to year is most striking. When judged on the basis of relative percentages of wormy apples (compare the three lower segments of the bars for each year), the *lighted unsprayed* areas appeared to occupy a position between the unlighted plats which received two cover sprays and those which received three. *Lighted unsprayed* plats compared with unlighted plats receiving three and four cover sprays show that the percentage of wormy apples is greater in the *lighted unsprayed* area, although the total amount of injured fruit in the unlighted area is, in some instances, greater. It would seem that a higher proportion of the injury in the sprayed plats is restricted to stings,

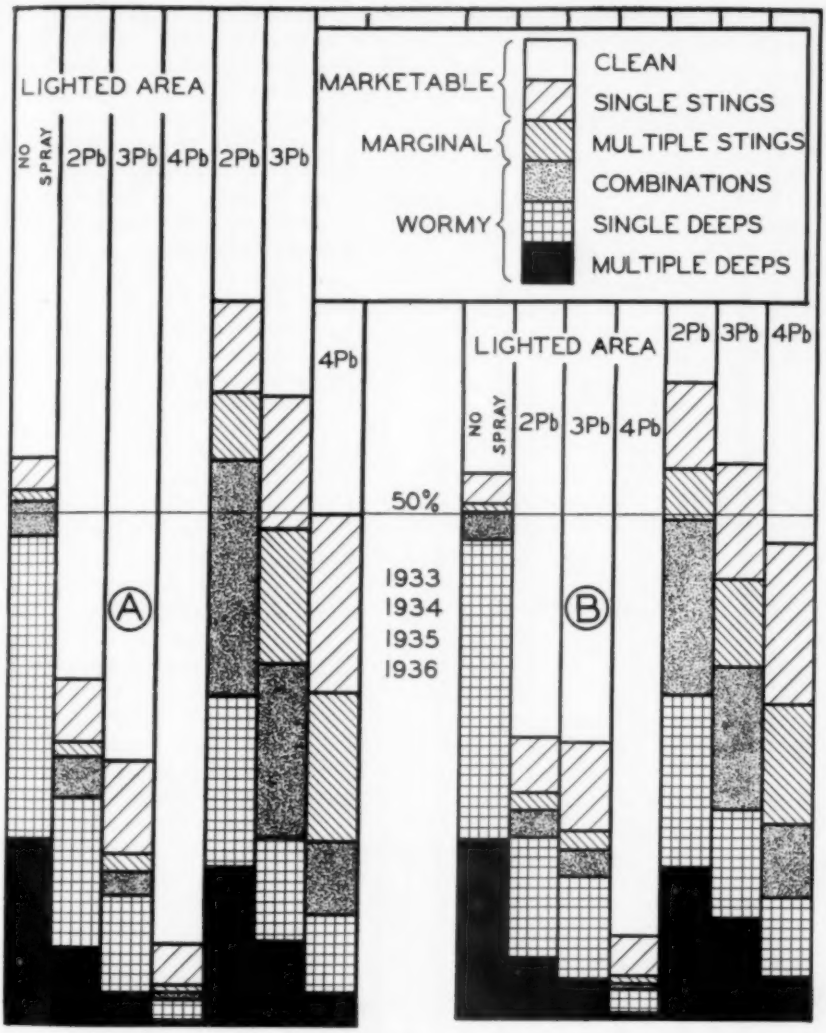

Fig. 2.—Percentages of codling moth injury in the several plats for the four-year period: *A*, on the basis of the unweighted mean (average of yearly percentages); *B*, on the basis of the weighted mean (percentages derived from sum totals of figures in each class).

whereas a higher percentage of caterpillars in the unsprayed plats succeed in effecting entrance. Two cover sprays alone, however, do not appear to have much more influence than light traps in restricting injury to stings. On the basis of marketable fruit (the two higher segments of each bar), the percentages are in general higher in the *lighted unsprayed* plats than in the *two cover sprays unlighted* plats. However, when the percentages of clean fruit are considered, the *lighted unsprayed* plats are

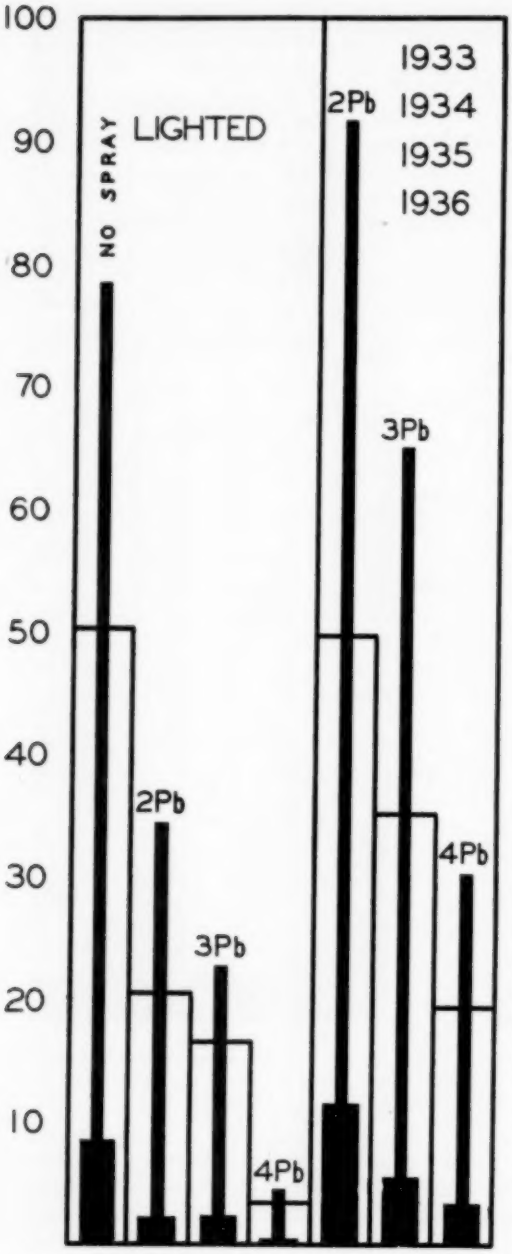

Fig. 3.—Four-year percentages of wormy fruit (open bars); number of caterpillars per 100 apples based on band counts (broad black bars); and number of wormholes per 100 apples (narrow black bars). All figures on basis of weighted mean.

generally comparable to the *three cover sprays unlighted* plats. It is consistently true on all of these bases of comparison that each lighted sprayed plat was better than the corresponding unlighted plat receiving the same number of cover sprays.

The difficulties involved in assigning a proper value to light traps as a control measure, in spite of the general consistency of the data, are obvious from some of the above comparisons. The lack of sufficient data from certain plats, as explained earlier in this discussion, is probably responsible for some of the discrepancies. It was felt not only that a closer approximation of the true relationships between the different plats could be gained from a consideration of the data from the four years taken together, but that such a treatment would afford a certain amount of compensation for inadequate numbers of apples or trees in a given plat during any one year. Whether the relative numbers of apples involved are taken into consideration by using the "weighted" mean, as in figs. 2b and 3, or whether they are ignored, as in fig. 2a, by averaging percentages, the relationships which were more or less apparent in the yearly

charts, fig. 1, are more clearly distinguishable. When the relative numbers of caterpillars and of wormholes are considered, fig. 3, the *lighted unsprayed* area occupies a position between the *two cover sprays unlighted* and the *three cover sprays unlighted* plats. A consideration of the "wormy" segments, reproduced on this same chart, places the position of the *lighted unsprayed* plat closer to that of the *two cover sprays unlighted* plat. This relationship is equally apparent when the percentages are expressed on the basis of the "unweighted" mean.

From the foregoing charts and data it is indicated that the light traps exerted an influence on the codling moth infestation sufficient to be reflected in a measurable decrease in injury to the fruit. An evaluation of this influence on the basis of the different methods of comparison used leads to the inference that, under the given experimental conditions, the control achieved by light traps was comparable to that secured by the application of two cover sprays of lead arsenate.—5-6-37.

Effect of Different Spreaders on Thrips Control by Nicotine

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In recent years Louisiana growers have failed to control thrips satisfactorily with sprays of nicotine sulfate. This fact was again demonstrated in the spring of 1936 when experiments were set up to determine the value of a number of liquid spreaders with nicotine sulfate in the control of thrips on several truck crops.

Recent work of Tate & Andre (1936) has shown that the large amount of nicotine required to kill *Thrips tabaci* Lind. and *Taeniothrips simplex* (Morison) makes its use for commercial control of thrips economically impractical.

It was the purpose of this study to determine why growers were not obtaining satisfactory results with nicotine sulfate, and to determine whether nicotine sulfate could be economically used with proper spreaders and activators for the control of thrips. This study is not yet completed, but several important phases of the problem are analyzed and reported in this paper.

It was found that the species of thrips that injure garden and truck crops in Louisiana were *Frankliniella fusca* Hinds, *Frankliniella tritici* Fitch, and *Thrips tabaci* Lind. Of these, *Frankliniella fusca* was by far the most destructive, especially to shallots, onions and cabbages. In Louisiana this species is the common garden thrips. *Thrips tabaci* was found only during the winter season, and then only in small numbers. Therefore, *Frankliniella fusca* was used in the toxicity tests.

In these tests commercial forms of nicotine were used, including 95 per cent free nicotine and nicotine sulfate containing 40 per cent nicotine (*Black Leaf 40*). Forty per cent free nicotine (*Nicofume*) and 50 per cent

free nicotine (*Black Leaf 50*) were tested also to ascertain whether they gave corresponding results.

The spreaders used in the series of toxicity tests were liquid tar soap, *E 25–61*,[1] and *EP 3*. *EP 3* was composed of *E 25–61*, 95 per cent, and *Palustrex*, 5 per cent. Other spreaders used in fewer tests were mono-amyl-amine oleate, *Red Arrow*, *Aresket*, *F.A.C.* oil, *ODTA*, and various solid soaps such as *Ivory* flakes, olive-oil flakes, and tar soap flakes.

Powdered Karaya gum, a product derived from a tropical plant, *Cochlospermum gossypium*, was found to increase markedly the toxicity of nicotine. In these tests, 1 part of the Karaya gum was used to 500

Table 1.—Results of spray tests for the control of *Frankliniella fusca* Hinds on shallots.

Spray	No. Tests	Av. No. Thrips Sprayed	Av. No. Thrips Killed	Av. Per Cent Thrips Killed	Av. No. Thrips Recovered	Av. Per Cent Thrips Recovered
Liquid tar soap 1:250, 95% nicotine 1:1800	10	17.9	16.7	91.9	1.2	8.1
Liquid tar soap 1:250, nicotine sulfate 1:250	10	12.2	10.6	86.2	1.6	13.8
Liquid tar soap 1:250, Karaya gum 1:500, 95% nicotine 1:8000	10	18.9	16.5	86.8	2.4	13.2
Liquid tar soap 1:250, Karaya gum 1:500, nicotine sulfate 1:4000	10	18.8	16.9	92.2	1:9	7.8
E 25–61 1:800, 95% nicotine 1:800	10	21.	19.4	90.1	1.6	9.9
E 25–61 1:800, nicotine sulfate 1:125	10	11.6	10.3	89.6	1.3	10.4
E 25–61 1:800, Karaya gum 1:500, 95% nicotine 1:8000	10	21.5	19.6	89.8	1.9	10.2
E 25–61 1:800, Karaya gum 1:500, nicotine sulfate 1:800	10	13.2	11.9	87.1	1.3	12.9
EP 3 1:800, 95% nicotine 1:2200	10	18.9	17.4	93.1	1.5	6.9
EP 3 1:800, nicotine sulfate 1:500	10	19.3	17.7	90.6	1.6	9.4
EP 3 1:800, Karaya gum 1:500, 95% nicotine 1:8000	10	23.2	21.5	90.6	1.7	9.4
EP 3 1:800, Karaya gum 1:500, nicotine sulfate 1:800	10	15.6	14.4	91.6	1.2	8.4

parts of the spray. To use the Karaya gum it was necessary to prepare a jell consisting of 1 part of Karaya gum and 50 parts of water. It was necessary to add the water in small amounts while mixing, so that the Karaya gum would take it up and form the jell without lumping and with a minimum amount of work. Making the jell was the most difficult part of the procedure. After this step was completed the jell was easily diluted in preparing the liquid spray.

Spray tests were conducted on individually potted shallot plants that were infested with adults of *Frankliniella fusca*. Filter paper was fitted about the base of the plant so that no soil was exposed, and the plant was sprayed thoroughly with a pressure hand sprayer. The drenched thrips were removed from the plant with a camel's-hair brush, placed on the filter paper, and the number of insects recorded. At the end of 24 hours the dead thrips were counted. It was found that those that had not recovered within 24 hours never revived. This method of testing was adopted as it was thought that it would simulate field conditions as far as it was possible to do under insectary conditions.

The final results from each spray were based on a series of 10 tests, not more than two of which were run on the same day. The series of 10 toxicity tests was run with each of the three spreaders in combination

[1] For composition see Eddy (1936).

with (1) 95 per cent free nicotine, (2) nicotine sulfate, and (3) 95 per cent free nicotine and Karaya gum, and (4) nicotine sulfate and Karaya gum.

To secure adequate wetting and spreading on the shallots, it was necessary to dilute the spreaders as follows: liquid tar soap 1:250, *E 25–61* 1:800, and *EP 3* 1:800.

Preliminary tests were conducted to ascertain the concentration of nicotine and nicotine sulfate required to kill approximately 90 per cent of the *Frankliniella fusca*. The final tests were then run at these concentrations. Table 1 shows the results of these experiments.

From the tests it was evident that nicotine sulfate, when used alone with a spreader, was not killing thrips at a concentration equivalent to that of 95 per cent free nicotine. In a series of experiments it was found that this condition could be overcome by the addition of potassium hydroxide to the spray solution at the rate of 4 ounces to each 100 gallons of spray mixture. It may be noted from table 1 that when *Palustrex* was added to *E 25–61* to make the formula *EP 3*, better results were obtained with nicotine and nicotine sulfate.

The solid soaps tested did not seem to need additional alkali, since nicotine sulfate, when used with them, killed at the same concentration as it did with the liquid soaps to which KOH had been added. Experiments showed that the tar soap flakes gave much better results with nicotine sulfate than did the liquid tar soap, but was improved by the use of the additional alkali. This improvement was not as pronounced as with the liquid tar soap.

It was found that bicarbonate of soda was of very little value, even when used in relatively large amounts, as a substitute for potassium hydroxide.

The addition of Karaya gum to the spray combinations increased their effectiveness to a marked degree. It not only seemed actually to increase the toxicity of nicotine, but also to overcome, in part, a certain amount of apparent alkali deficiency. The Karaya gum apparently rendered additional alkali unnecessary in the case of liquid tar soap, *Red Arrow* soap and mono-amyl-amine oleate, but not in the case of *E 25–61* and *EP 3*. This fact led to the deduction that the last two spreaders need even more alkali than the others for use with *Frankliniella fusca*. When using Karaya gum in a preliminary test at the rate of 1:250 it appeared that this amount overcame the apparent alkali deficiency of these two spreaders.

Results.—KOH added to liquid tar soap, *Red Arrow*, *E 25–61* and *EP 3* made nicotine sulfate toxic to *Frankliniella fusca* at normal dilutions. Without the alkali the full amount of the nicotine apparently was not being liberated, or was not being liberated rapidly enough to kill.

Karaya gum increases the effectiveness of all nicotine sprays.

(1) With *E 25–61* it increased the nicotine sulfate dilution from 1:125 to 1:800.

(2) With liquid tar soap it increased the nicotine sulfate dilution from 1:250 to 1:4000.

(3) With *EP 3* it increased the nicotine sulfate dilution from 1:800 to 1:5000.

(4) With *E 25–61* it increased 95 per cent free nicotine dilution from 1:1800 to 1:8000.

(5) With liquid tar soap it increased 95 per cent free nicotine dilution from 1:1800 to 1:8000.

(6) With *EP 3* it increased the 95 per cent free nicotine dilution from 1:2200 to 1:8000.

Using a weak base soap, mono-amyl-amine oleate at 1:1000, nicotine sulfate gave control at 1:600. When Karaya gum was added, the nicotine sulfate killed at 1:4000, and 95 per cent free nicotine at 1:8000.

When KOH was used at the rate of 4 ounces to 100 gallons:

(1) With *E 25–61*, the alkali increased the dilution of nicotine sulfate from 1:125 to 1:800.

(2) With liquid tar soap, the alkali increased the dilution of nicotine sulfate from 1:250 to 1:800.

(3) With *EP 3*, the alkali increased the dilution of nicotine sulfate from 1:500 to 1:800.

(4) With mono-amyl-amine oleate, the alkali increased the dilution of nicotine sulfate from 1:600 to 1:800.

Summary.—The experiments reported show that the failure of spray mixtures containing nicotine sulfate to kill *Frankliniella fusca* Hinds was due to a deficiency in several spreaders which was corrected by the addition of KOH.

Karaya gum added to the sprays markedly increased their effectiveness.—4-23-37.

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Karaya Gum in Nicotine Sprays

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In a study that was made of many materials to determine their individual effects in nicotine sulfate–soap spreader combinations, Karaya gum so increased the effectiveness of the spray that it was possible to reduce greatly the amount of nicotine.[1] When this fact was established, definite experiments were undertaken to ascertain the exact value of Karaya gum in nicotine sulfate–soap spreader sprays in the control of an aphid, *Tritogenaphis ambrosiae* (Thomas), on the great ragweed, *Ambrosia trifida* L.

Nicotine sulfate containing 40 per cent nicotine was used as a source of nicotine. Liquid tar soap 4:1000, *E 25–61*[2] 1:1000 and mono-amyl-

[1] A part of the initial work in the problem of comparing materials from many sources to increase the effectiveness of nicotine spray was done by the senior author at the Kentucky Agricultural Experiment Station during 1935.

[2] For composition see Eddy (1936).

amine oleate 1:1000 were used as spreaders. Karaya gum was used at the rate of 1:500.

A powdered Karaya gum, derived from the tropical plant, *Cochlospermum gossypium*, was used. Before adding it to the spray mixture a 1 per cent jell was made by slowly adding water to the powdered Karaya gum, while stirring it vigorously. This was done very carefully to avoid

Table 1.—Tests of various combinations of soaps, nicotine sulfate, and Karaya gum in aqueous sprays against *Tritogenaphis ambrosiae* (Thomas).

Spray	No. Tests	Av. No. Aphids Sprayed	Av. No. Aphids Killed	Av. Per Cent Aphids Killed	Av. No. Aphids Recovered	Av. Per Cent Aphids Recovered
Liquid tar soap 4:1000, nicotine sulfate 1:800	15	6	5.33	88.8	.66	11.2
Liquid tar soap 4:1000, nicotine sulfate 1:2000	4	6	4.	53.3	2.	47.7
Liquid tar soap 4:1000, Karaya gum 1:500, nicotine sulfate 1:800	25	6	5.76	96.	.24	4.
Liquid tar soap 4:1000, Karaya gum 1:500, nicotine sulfate 1:1500	25	6	5.76	96.	.24	4.
Liquid tar soap 4:1000, Karaya gum 1:500, nicotine sulfate 1:2000	4	6	5.5	91.6	.5	8.4
E 25–61 1:1000, nicotine sulfate 1:800	15	6	5.2	86.6	.8	13.4
E 25–61 1:1000, nicotine sulfate 1:2000	4	6	3.25	54.16	2.75	45.84
E 25–61 1:1000, Karaya gum 1:500, nicotine sulfate 1:800	25	6	5.76	96.	.24	4.
E 25–61 1:1000, Karaya gum 1:500, nicotine sulfate 1:1500	25	6	5.56	92.6	.44	7.4
E 25–61 1:1000, Karaya gum 1:500, nicotine sulfate 1:2000	4	6	5.5	91.6	.5	8.4
Mono-amyl-amine oleate 1:1000, nicotine sulfate 1:800	15	6	4.6	77.	1.4	23.
Mono-amyl-amine oleate 1:1000, nicotine sulfate 1:2000	4	6	1.75	20.8	4.25	79.2
Mono-amyl-amine oleate 1:1000, Karaya gum 1:500, nicotine sulfate 1:800	25	6	5.88	98.	.22	2.
Mono-amyl-amine oleate 1:1000, Karaya gum 1:500, nicotine sulfate 1:1500	25	6	5.6	93.3	.4	6.7
Mono-amyl-amine oleate 1:1000, Karaya gum 1:500, nicotine sulfate 1:2000	4	6	5.25	87.5	.75	12.5
Liquid tar soap 1:1000, Karaya gum 2:1000	4	6	.75	12.5	5.25	87.5
Liquid tar soap 1:1000, Karaya gum 2:1000, nicotine sulfate 1:2000	4	6	5.5	91.6	.5	8.4
Liquid tar soap 1:1000, Karaya gum 2:1000, nicotine sulfate 1:2000, KOH 2 pellets:100	4	6	5.5	91.6	.5	8.4
E 25–61 1:1000, nicotine sulfate 1:400	4	6	5.5	91.6	.5	8.4
Liquid tar soap 1:250, nicotine sulfate 1:400	4	6	5.75	95.6	.25	4.4
Mono-amyl-amine oleate 1:1000, nicotine sulfate 1:400	4	6	5:25	87:5	.75	12:5

the formation of lumps. After the jell was made the gum mixed easily with the spray mixtures.

To test each spray mixture, a tip of the plant *Ambrosia trifida* L., infested with six aphids, was placed in a glass bottle and sprayed while the plant was rotated through 360 degrees, so that all the aphids were wet thoroughly. The bottle was then placed on a paper plate in an outdoor insectary and mortality records were made at the end of 24 hours.

Preliminary tests were conducted to ascertain the concentration of nicotine sulfate with Karaya gum at the rate of 1:500 which was required to kill approximately 90 per cent of the *Tritogenaphis ambrosiae* (Thomas). The final tests were then run at these concentrations. Table 1 shows the results of the trials. Tests were also run on *Aphis rumicis* L. on nasturtium. Details of this series are not included, but the results are given.

It was found that Karaya gum wetted easily with pine oil, including *Palustrex*, light grades of mineral oil, including kerosene, and a number of other materials used in contact spray combinations, without forming a jell. The soap spreaders mixed readily with these combinations and then diluted with water instantly without the difficulties involved in mixing the water with the Karaya gum. The addition of the pine oils and mineral oils added to the effectiveness of the combination. They were used at a concentration ranging from 1 pint to 2 quarts per 100 gallons of spray mixture.

Results.—*Tritogenaphis ambrosiae* (Thomas) was a difficult aphid to kill with nicotine sulfate–soap spreader combinations. It required a dilution of 1:400 to kill effectively.

When used at the rate of 1:500, Karaya gum increased the dilution at which nicotine sulfate was effective in the control of *Tritogenaphis ambrosiae* (Thomas) as follows:

(1) With *E 25–61*, from 1:400 to 1:2000.
(2) With liquid tar soap, from 1:400 to nearly 1:2000.
(3) With mono-amyl-amine oleate, from 1:400 to 1:2000.

In similar experiments with *Aphis rumicis* L., nicotine sulfate–soap spreader combinations killed as effectively at 1:2000 with Karaya gum (1:500) as at 1:800 without the Karaya gum.

Karaya gum–soap spreader combinations without nicotine were ineffective.

Summary.—Karaya gum greatly increased the effectiveness of nicotine sulfate–soap spreader combinations on two species of aphids. By using the gum (1:500), one-fifth to one-third of the nicotine sulfate was effective.—4-23-37.

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Experiments to Control Hairy Chinch Bug Infesting Turf on Long Island

G. F. MacLeod and Kenneth E. Maxwell,[1] *Cornell University Ithaca, N. Y.*

Many attempts have been made to control chinch bugs on lawn grasses in different sections of the country. Investigators working with chinch bugs on St. Augustine grass lawns in Florida have reported satisfactory control from various materials. Newell & Berger (1921) reported good results with tobacco dust, soap and nicotine–soap sprays. Beyer (1924) obtained high kills with calcium cyanide dusts. Watson & Bratley (1929) recommended, in addition to calcium cyanide, a nicotine–lime dust, tobacco dust and nicotine–soap spray. Wilson (1929) suggested a nicotine–soap spray. Among workers attempting control of chinch bugs

[1] Studies conducted under a fellowship grant of the North Shore Private Estates Association in cooperation with the Nassau County Farm Bureau.

on northern lawn grasses, Howard (1898) reported that a kerosene emulsion was effective. Felt & Brom- (1931) obtained the best kills from nicotine–soap spray and *Cyanogas A* dust, but the latter gave some burning. Walden (1935) reported satisfactory control with a spray of nicotine sulfate and soap. Houser (1936) did not find nicotine sprays to be effective but obtained satisfactory control form nicotine–lime dust, tobacco dust and *Cyanogas G Fumigant*, although slight burning was caused by the latter. Hamilton (1935) obtained best results with a derris dust.

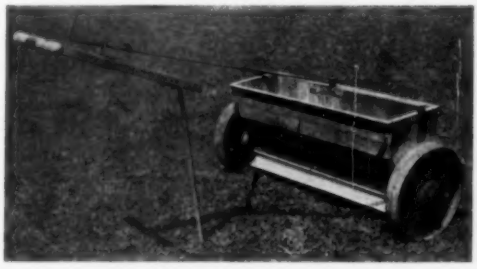

Fig. 1.—Distributor used for applying tobacco and rotenone dust.

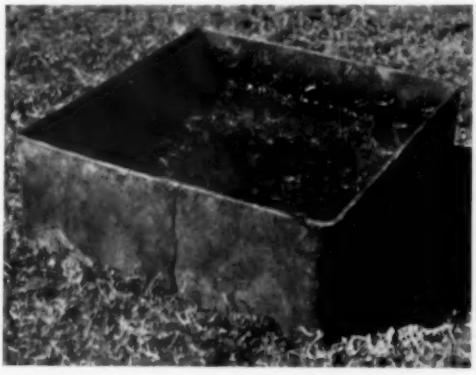

Fig. 2.—Frame used in making population counts.

In a previous paper Maxwell & MacLeod (1936) discussed the status of the hairy chinch bug, *Blissus hirtus* Montadon, its injury to turf, life history and some experiments for its control on Long Island. In tests with various materials, tobacco dust, rotenone dust and nicotine–soap sprays gave the most promising results. Experiments discussed in the present paper consisted of plots of lawn and putting-green grass treated with those materials at various concentrations, rates and times of application. The dust materials were applied by means of a lime distributor which could be adjusted to regulate the amount of flow, fig. 1. All dust materials were raked or brushed into the grass, and in some of the experiments were also washed in. The spray materials were applied by means of a power machine, the nozzle being held vertically about 1 foot above the surface of the grass. The most satisfactory apparatus for population counts was found to be an iron frame, 1 foot square, 5 inches high and open at the top and bottom, fig. 2. It was sharpened along the bottom edge to facilitate driving into the turf. When water at a temperature of 40° C was poured into the frame the chinch bugs became very active and readily came to the surface of the water, where they could be counted and removed. Ten to 15 minutes were adequate for all the chinch bugs within the frame to rise to the surface. With experiments conducted where hot water was not available, a 1:2400 solution of *Evergreen* was used to bring the chinch bugs to the surface.

Experiments for the control of chinch bugs of the first brood were

made on a mixture of redtop and seaside creeping (Coos county) bent grass. The general plan consisted of linear plots 7 feet wide by 60 feet long with three replications for each treatment. Half of each plot received one application and the other half received two applications, fig. 3. On plots which received two applications the first was applied the first week of June and the second two weeks later, June 16. All plots which received only a single application were treated June 16. The spray was applied at the rate of about 240 gallons to 1000 square feet and the dust materials at the rate of 25 pounds to 1000 square feet. The spray consisted of 40 per cent nicotine sulfate 1:400 with 40 per cent potassium oleate soap 1:100. All dust-treated plots were raked, and both dusted and sprayed plots were watered immediately following application. There was no injury from any of the dust treatments although the nicotine–soap spray resulted in burning which was evident for several days. The numbers of chinch bugs to the square foot, table 1, first brood, were obtained from an average of 30 observations. Analysis of the data by the variance method (Snedecor, 1934) indicated that all treatments gave significant reductions in populations over the checks and that populations in the plots treated twice were significantly lower than in plots which received only one application. The checks suffered severe damage from chinch bugs by July 10 and there was slight damage in some of the plots which received only one application. Satisfactory control of the first brood was obtained with all materials in plots receiving two applications.

Table 1.—Results of experiments for the control of chinch bugs infesting bent grass.

Material	No. Chinch Bugs per Square Foot	
	One Application	Two Applications
First Brood		
Tobacco dust 1% nicotine	40.9	11.1
Cubé dust, 1% rotenone	20.4	8.
Nicotine–soap spray	43.9	15.3
Check	*92.4*	*91.4*
Difference to be significant,	25.6	
Second Brood		
Tobacco dust, 1% nicotine	13.5	5.5
Cubé dust, 1% rotenone	21.9	9.7
Nicotine–soap spray	39.3	14.2
Tobacco dust .75% nicotine*	9.7*	3.6*
Difference to be significant, 5.3		

* Received no treatment against first brood.

Table 2.—Results of experiments using one application against each brood of chinch bugs infesting lawn grass.

Material	No. Chinch Bugs per Square Foot	
	25 Lbs. per 1000 Sq. Ft.	50 Lbs. per 1000 Sq. Ft.
Tobacco dust, 75% nicotine	9.9	1.
Tobacco dust, 1% nicotine	7.8	1.6
Cubé dust .5% rotenone	5.2	1.3
Cubé dust, 1% rotenone	4.6	1.5
Difference to be significant, 3.8		

Table 3.—Effectiveness of tobacco dusts for the control of second-brood chinch bugs on bent grass.

Material	Pounds per 1000 Square Feet	No. Applications	No. Chinch Bugs per Square Foot
Tobacco dust, 1% nicotine	25	2	.33
Tobacco dust, 1% nicotine	50	1	.72
Tobacco dust, .75% nicotine	50	1	.72
Check			*31.7*
Difference to be significant, 7.63			

The same treatments were repeated on the same plots for the second brood, table 1, second brood, with the exceptions that the first-brood checks were treated with tobacco dust containing .75 per cent nicotine and none of the dust materials were washed in following applications.

The amount of the spray was reduced to 120 gallons per 1000 square feet and the grass was watered immediately following application, but slight burning was again evident. Differences between materials were, in most cases, highly significant. In every case, two applications were significantly more effective than one. In general, all of the treatments satisfactorily protected the grass except in the case of nicotine spray, where there was evidence of insect injury. The low population in the plots treated with tobacco dust containing .75 per cent nicotine may have been due partly to the fact that a large portion of the grass in these areas was destroyed by the first brood when these plots served as checks.

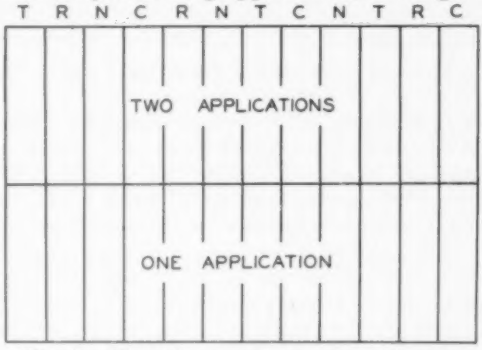

Fig. 3.—Plan of experiments on seaside creeping bent grass. *T*, tobacco dust; *R*, rotenone dust; *N*, nicotine—soap spray; *C*, control (no treatment).

Table 4.—Populations of chinch bugs in and injury to different varieties of lawn and putting-green grass.

Variety	Chinch Bugs per Sq. Foot	Degree of Damage
Experiment I		
Fine-leaved fescue	1.7	slight
Rough-stalked meadow	2.3	slight
Pacey's rye	3.3	slight
European red fescue	8.	slight
Sheeps fescue	11.5	slight
Astoria colonial bent	23.8	slight
N. Z. colonial bent	27.9	slight
Canada blue	27.9	slight
Kentucky	47.8	moderate
Chewing's N. Z. fescue	49.4	moderate
Redtop	49.4	severe
Seaside creeping bent	54.3	severe
German mixed bent	59.5	severe
Mixture*	67.1	severe
Velvet bent	136.7	severe
S. E. of means, 18.4 per cent		
Experiment II		
Kentucky blue	2.	slight
Chewing's N. Z. fescue	7.1	slight
Redtop	68.	severe
Prince Edward Island bent	141.2	severe
S. E. of means, 38.4 per cent		

* One-half Coos county bent, one-quarter redtop and one-quarter Chewing's N. Z. fescue.

The results of experiments with rotenone and tobacco dusts, using one application for each brood at 25 and 50 pounds to 1000 square feet, are given in table 2. Treatments were made June 17 and August 14. All materials used in this experiment were raked in and watered following application. Greater reductions in populations were obtained with the 50-pound rate than with the 25-pound rate but very little damage occurred in any of the plots.

Further experiments for the second brood included tobacco dusts containing .75 and 1 per cent nicotine used at different rates, table 3. Single applications were made August 7 and double applications on August 7 and August 21. The materials were raked in but the grass was left dry with no subsequent burning. Because the infestation was light, none of these plots

received any treatment for the first brood. Grass in the untreated checks was injured by the second brood of chinch bugs. All treatments controlled the insects but there were no significant differences between treatments.

Several varieties of grass used for northern lawns and putting greens were grown for observations on their relative susceptibility to chinch bug damage. The plots received no treatments for diseases or insects. The numbers of chinch bugs to the square foot given in table 4 are averages of 10 observations. Velvet bent, which suffered severe injury, had the highest population of chinch bugs, table 4, experiment I. Triple A (Astoria colonial bent) and New Zealand colonial bent, both strains of *Agrostis tenuis*, had lower chinch bug populations and were in better condition at the end of the season than any of the other bent grasses. The fined-leaved fescue appeared to be highly resistant to chinch bug damage although its value as a lawn grass has not been established. In other studies, table 4, experiment II, Kentucky bluegrass was of a better quality at the end of the season than any of the other varieties included in the experiment. The degree of damage was approximately proportional to the chinch bug population. The differences in chinch bug populations in Kentucky bluegrass and Chewing's New Zealand fescue in experiment I as compared to experiment II, table 4, may be explained by the fact that the experiments were conducted in two different localities. Obviously, cultural and environmental conditions influenced the density of chinch bugs in the grasses in these two areas.

Summary.—There are two broods of chinch bugs each year on Long Island. Applications for the first brood were made during the first half of June and those for the second brood during the first half of August. Treatments for each brood were applied after most of the eggs had hatched but before the young bugs caused damage. Satisfactory control of heavy infestations of chinch bugs was obtained by each of the following materials, using two applications against each brood: tobacco dust containing 1 per cent nicotine or cubé dust containing 1 per cent rotenone at the rate of 25 pounds to 1000 square feet for each application, or a spray consisting of 40 per cent nicotine sulfate 1:400 with 40 per cent potassium oleate soap 1:100, applied at the rate of about 240 gallons to 1000 square feet. In some cases one application gave adequate control. Two applications against each brood were more effective than one in reducing populations and one application of 50 pounds of dust was more effective than one of 25 pounds to 1000 square feet. Tobacco and rotenone dusts gave consistently better results than the nicotine–soap sprays and the latter caused burning in each case. Tobacco dust was equal or superior to the other materials and was more satisfactory from the standpoint of cost. The evidence indicated that the tobacco dust need not be watered in. In an experiment dealing with a light infestation of chinch bugs, tobacco dust containing .75 per cent nicotine and cubé dust containing .5 per cent rotenone gave effective control.

Certain varieties of northern lawn and putting-green grass were highly susceptible to chinch bug injury. These included velvet bent, German mixed bent, seaside creeping bent and redtop. Astoria colonial bent, New Zealand colonial bent, Kentucky bluegrass and Chewing's

New Zealand fescue appeared to be less susceptible to injury under certain conditions.—1-11-37.

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Dusting to Control Strawberry Weevil in Virginia

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The strawberry weevil, *Anthonomus signatus* Say, is sometimes a serious pest of strawberries on the eastern shore of Viginia. This has been especially true the past three years in the northern part of Accomac county. Some of the fields observed had as high as 75 per cent of the buds cut by the ovipositing weevils.

A field of Big Joe strawberries, known to have been heavily infested with this insect in 1935, was selected for this experiment on E. A. Hall's farm near Temperanceville, Va. This strawberry planting was three years old and was bordered on three sides by pine forests with heavy underbrush and trash, which furnished ideal hibernating quarters for the overwintering weevils. This pest was plentiful in the field by April 20, 1936, and had cut 5 to 7 per cent of the buds. By the time arrangements could be made for the first treatment on April 23, 17 per cent of the buds had been cut, indicating that the weevils were very active at this time. A second and final application of dust was made on April 29.

Four different dust insecticides and an untreated check were included in this experiment. The ingredients and proportions by weight of each dust used were as follows: finely ground dusting sulfur–lead arsenate, 5:1; hydrated lime–lead arsenate, 5:1; finely ground dusting sulfur–

calcium arsenate, 5:1; and finely ground dusting sulfur–finely ground derris root containing 5 per cent rotenone, 17:3.

Each material was applied at the rate of 40 pounds per acre per application to plats of four beds, 5 feet wide by 120 feet long, replicated four times. Untreated check plats of similar size were included with each replication. Treatments were made with a *Niagara* six-nozzle one-horse traction duster equipped with a 20-foot burlap trailer covering one bed at a time.

Records were taken of the relative number of buds cut by counting three representative samples of 100 buds in each plat, making a total of 1200 buds for each treatment. Such counts were made on April 24, 29

Table 1.—Results of dusting strawberries in 1936 for control of the strawberry weevil.

Materials	Per Cent of Buds Cut*	Yield in Quarts per Acre†	Per Cent Increase in Yield over Untreated
Sulfur–lead arsenate 5:1	15	390	62
Lime–lead arsenate 5:1	14	390	62
Sulfur–derris (.75% rotenone)	14	350	45
Sulfur–calcium arsenate 5:1	7	318	35
Untreated	39	241	

* A difference of 6.27 may be considered significant. † A difference of 59.9 may be considered significant.

and May 6. Very little injury occurred after May 6. Yield records were taken on May 22 and 25.

The insecticides used, per cent of buds cut after beginning the experiment, yields of berries, and per cent increase in yield due to treatment are given in table 1. As shown in this table, the treated plats produced significantly higher yields and had a lower per cent of buds cut than the untreated plats. Although the plats treated with the sulfur–calcium arsenate dust had the least number of buds cuts, they did not yield so well as the other treated plats because this material caused marked foliage injury. The sulfur–lead arsenate, lime–lead arsenate, and sulfur–derris dusts gave about the same weevil protection, but for some unknown reason the sulfur–derris treated plats fell slightly below the other two in yield. Heavy frosts and freezes on April 24 and 25 and later drouths reduced the yields about 80 per cent below normal in all plats.

Since the red spider, *Tetranycus telarius* Linné., is frequently a serious pest in this area, the sulfur–lead arsenate dust is preferred to the hydrated lime–lead arsenate dust because it gives protection against this pest. The sulfur–derris dust may be used to eliminate the danger of an arsenical residue in fields where early berries have set at the time of treatment.—3-15-37.

The requirement of fumigation of nursery stock as a condition of entry from alfalfa-weevil infested areas was lifted by the states of Colorado and New Mexico under revisions of their quarantines in March 1937. Changes were also made in the areas designated as infested with the weevil.

Pea Aphid Control in Maryland

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In 1932 the pea aphid[1] problem reached such proportion in Garrett county, Md., that many growers refused to contract for planting in the future. It was evident that the pea industry in this county, involving about 600 acres, would be lost if something was not done to control this pest. Accordingly the University of Maryland, Department of Entomology, started experiments to determine the effectiveness of different materials for pea aphid control.

At the time these investigations were started the pods were grown, and all that remained green of the vines were the buds where the aphids had congregated, thereby fully exposing the aphids to the spray. The records were made by shaking all the aphids on the ground and counting the dead and live ones from a definite area on each plot. The different materials were applied with a four-row potato sprayer and the following results obtained:

Pyrote (pyrethrum–rotenone compound), 1 gallon to 400 gallons of spray gave 89.78 per cent kill.

Pyrethrol (2 grams of pyrethrins per 100 cc.), 1 gallon to 200 gallons of spray gave 57 per cent kill.

Penetrol, 1 gallon to 200 gallons of spray, plus 1 pint of nicotine sulfate gave 58 per cent kill.

Chipso soap 4 pounds, and nicotine sulfate 1 pint to 100 gallons of spray, gave 74 per cent kill.

Potassium fish-oil soap 4 pounds, nicotine sulfate 1 pint to 100 gallons of spray, gave 80 per cent kill.

Potassium fish-oil soap 4 pounds, plus nicotine sulfate 1 pint to 100 gallons of spray, in another test gave 60 per cent kill.

After observing the tests in 1932 the owners of the Mt. Airy Canning Company purchased a *Bean* spray machine to be used in 1933 and later. The machine was equipped with a 400-gallon tank, 30 spray nozzles set 1 foot apart, and was mounted on a truck. The spraying speed of the truck was 15 miles per hour; it carried 600 pounds of pressure, and put out 100 gallons of spray per acre. The time required to cover an acre was approximately five minutes.

Field tests with nicotine sulfate plus soap.—The field tests in 1933 consisted of the use of nicotine sulfate, 1 pint to 100 gallons of spray, plus 4 pounds of potassium fish-oil soap. Examination in six fields showed that before the spray was applied there was an average of 77.46 aphids per tip, and 10 days later an average of 7.35 aphids per tip. Examination in four other fields, 48 hours after the spray was applied, showed that 33.77 per cent of the aphids were dead. Other tests with a hand rotary duster and a compressed air sprayer gave the following results:

Red Arrow (2 grams of pyrethrins per 100 cc., and 38 per cent actual soap), 1:800 gave a decrease in aphids of 57.8 per cent.

Gem (40 per cent potash, coconut-oil soap), 1:300 gave a decrease in aphids of 82.15 per cent.

[1] *Illinoia pisi* Kalt.

Three per cent nicotine dust gave a decrease in aphids of 83.93 per cent.

Four per cent nicotine dust gave a decrease in aphids of 98.46 per cent.

Five per cent nicotine dust gave a decrease in aphids of 70.81 per cent.

In 1934, four half-acre plots were laid out in each of two pea fields. In field No. 1 the plots were on level, well-drained soil. In field No 2 plots No. 1 and 2 were on a steep hillside; plot No. 3 was on a less steep slope and plot No. 4, which was the check, was on practically level soil. All plots in both fields, except the two checks, were sprayed with a solution of nicotine sulfate, 1 pint, and potassium fish-oil soap, 4 pounds to 100 gallons of spray.

In field 1, plot No. 4 was used as a check and produced 742 pounds of shelled peas per acre. Plot No. 1 received two applications of spray. The first application was made June 22 when the peas were in full bloom. The second was applied June 29. The aphid infestation one day before the first application was applied averaged 28 per tip; one day after the spray was applied the infestation averaged 16 per tip. The aphid infestation one day before the second application was applied averaged 34 per tip; two days after the second application was applied it averaged .5 per tip. The yield in shelled peas per acre was 931 pounds, or an increase over the check of 25.4 per cent. Plot No. 2 received one application of spray on June 22 when the peas were in full bloom. The aphid infestation averaged 32 per tip before the spray was applied. One day after the spray was applied the infestation averaged 11 per tip. The yield in shelled peas per acre was 972 pounds, or an increase over the check of 30.9 per cent. Plot No. 3 received one application of spray on June 29, seven days later than the application made on plot No. 2. Half-grown pods were formed at this time. The aphid infestation before the application was applied averaged 77 per tip; one day after the spray was applied the infestation averaged 22 per tip. The yield in shelled peas was 972 pounds per acre, or an increase of 30.9 per cent over the check. In field No. 2, plot No. 4 was used as a check and produced 877 pounds of shelled peas per acre. Plot No. 1 received two applications of spray, the first was applied on June 25 four days before the peas came into bloom. The second application was applied June 29. The aphid infestation before the first spray was applied averaged 11 per tip, one day after the spray was applied the infestation averaged two per tip. The infestation before the second spray was applied averaged seven per tip, and one day after it was applied averaged one per tip. The yield in shelled peas was 664 pounds per acre, or 27.5 per cent less than the check. Plot No. 2 received one spray applied June 25, four days before the peas began to bloom. The aphid infestation before the spray was applied was six per tip; one day after the spray was applied the infestation was 2.4 per tip. The yield in shelled peas was 847 pounds per acre, or 3.53 per cent less than the check run in group 4. Plot No. 3 received one application of spray on June 29, when the peas were coming into bloom. The aphid infestation before the spray was applied averaged nine per tip, one day after the spray was applied the infestation averaged 12 per tip. The yield in shelled peas per acre was 919 pounds, or an increase over the check of 4.78 per cent.

The unfavorable yields in 1934 of plots 1, 2 and 3 in field No. 2 are attributed to the moisture content of the soil on the hillside. The season was extremely dry, and observations showed that the three plots on the hillside suffered much more severely than the check plot which was located on the level.

The field tests in 1935 were conducted the same as in 1934, except that the peas were in a different stage of development when the sprays were applied.

Plot No. 1, check, produced 1399 pounds of shelled peas per acre.

Plot No. 2 received one application of spray on June 26, four days before the peas began to bloom. The aphids present before the spray was applied averaged one per tip, four days after the spray was applied the infestation averaged eight per tip. The yield in shelled peas was 1548 pounds per acre, or an increase of 13.2 per cent over the check.

Plot No. 3 received two applications of spray, one on June 26, four days before the peas began to bloom and the second on July 1. The aphid infestation before the first spray was applied averaged three per tip; four days after the spray was applied the infestation averaged 1.9 per tip. The aphid infestation before the second spray was applied averaged 1.9 per tip; one day after the spray was applied the infestation averaged eight per tip. The yield in shelled peas was 1650 pounds per acre, or an increase over the check of 17.9 per cent.

Plot No. 4 received one spray on July 1 when the peas were beginning to bloom. The aphid infestation before the spray was applied averaged eight per tip; one day after the spray was applied the infestation was 1.1 per tip. The yield in shelled peas was 1601 pounds per acre, or an increase of 14.3 per cent over the check.

Field tests with derris.—In 1935 in the same field where the above nicotine and soap tests were conducted, the same size plots were laid out and a 3 per cent rotenone–derris dust, without a spreader, at the rate of 4 pounds per 100 gallons of spray, was applied at the same time as the above nicotine spray. Records were made on yield and aphid infestation. The results showed a slight decrease in aphid infestation and no increase in yield of peas over the check plot.

Field tests with nicotine sulfate plus soap and with derris plus spreader.—In 1936, nine plots, each 12 by 225 yards, were laid out for tests. Rotenone plus sodium lauryl sulfate spreader was used on four of the plots; nicotine sulfate plus soap on three. The remaining two plots, called 1 and 6, were used as checks. The average yield of the two check plots was 325 pounds of shelled peas per acre. The aphid infestation on the check plot, when the peas began to bloom, was 14.5 aphis per tip.

Plot No. 2 received one application of nicotine sulfate, 1½ pints, and potassium fish-oil soap, 4 pounds, to each 100 gallons of spray on June 18, about 10 days before blooming period. At this time there were no aphids present. On June 30 the aphid infestation averaged 10 per tip. The yield in shelled peas was 538 pounds per acre, or an increase over the check of 65.4 per cent.

Plot No. 3 received two applications of nicotine sulfate and fish-oil soap of the same strength as used in plot No. 2. The first application was applied on June 18, or about 10 days before blooming period, and

the second application was applied on June 30. There were no aphids present before the first application; on June 30 before the second application the average aphid infestation was 13.4 per tip, and 24 hours after the spray was applied the average infestation was 6.5 per tip. The yield in shelled peas was 666 pounds per acre, or an increase over the check of 104.9 per cent.

Plot No. 4 received an application of nicotine sulfate and soap of the same strength as was used in plots No. 2 and 3. The application was made on June 30, just after blooming started. Aphid infestation before the spray was applied averaged 46 per tip. Twenty-four hours later it averaged 18 per tip. The yield in shelled peas was 512 pounds per acre, or an increase over the check of 57.5 per cent

Plot No. 5 received one application of derris dust containing .75 per cent rotenone at the rate of 10 pounds plus one-half pound of sodium lauryl sulfate spreader to 100 gallons of spray at the beginning of blooming period. This plot produced 742 pounds of shelled peas per acre, an increase of 128.3 per cent over the check. The aphid infestation before the peas were sprayed was 15 per tip, 24 hours after the peas were sprayed it was two per tip.

Plot No. 7 received one application of derris dust containing rotenone at the rate of 6 pounds (active derris extractive material, including rotenone, 8 per cent) plus one-half pound of sodium lauryl sulfate spreader per 100 gallons of spray. This application was applied 10 days before the peas began to bloom, and produced 1128 pounds of shelled peas per acre, an increase of 247 per cent over the check plot. No aphids were present at the time the spray was applied. Twelve days later the infestation averaged .5 aphid per tip.

Plot No. 8 received two applications of derris dust containing rotenone, same strength and same spreader as plot No. 7. The first application was applied 10 days before blooming started, and the second application was applied when the peas began to bloom. The yield in shelled peas per acre was 1638 pounds, or an increase over the check of 404 per cent. There were no aphids present before the first application was applied, or two days after the last spray was applied.

Plot No. 9 received one application of derris containing rotenone, the same strength and spreader as in plots No. 7 and 8. Application was made when the peas first came into bloom. The yield in shelled peas per acre was 817 pounds or 151.3 per cent increase over the check. The aphid infestation just before the spray was applied was 14 per tip. Twenty-four hours after the spray was applied it was seven per tip.

At harvest time the rotenone treated plots were green and succulent, and pods were well formed and tender, whereas check plots and nicotine sulfate-treated plots were practically dead and the pods were poorly developed. Another index to the efficiency of derris dust containing rotenone over nicotine sulfate was the number of aphids on the ground after harvest. Under the derris–rotenone-sprayed plots only an occasional aphid could be found on the plot that received two applications, and a few more on the plots that received one application, whereas under the nictone sulfate-sprayed plots and check plots the ground was literally alive with aphids. The observations show that the rotenone remains

effective against the aphids over a much longer period than nicotine sulfate and soap.

Summary.—Five years' experience with soap and nicotine sprays has shown that their use results in large decrease of aphid infestation, and an increase in yield of shelled peas ranging from 13.2 to 104.9 per cent over the unsprayed plot.

One year's experience with derris dust containing rotenone without spreader showed a slight decrease in aphid infestation, and no increase in yield of peas over the unsprayed plots. The next year's experience with derris dust containing rotenone with spreader showed a decrease in aphid infestation in those plots that had an initial infestation, and an increase in yield of peas ranging from 128.3 to 404 per cent over the unsprayed plots. Highest yields, however, were from plots having no initial infestation. From the information obtained in these experiments it appears that the correct time to make the first application of spray is when the first aphids appear in the field. If the aphids come in about 10 days before the blooming period, it is advisable to apply a second application at the time the peas begin to bloom. However, if the aphid infestation starts at blossoming time only one application is necessary or economically useful.—4-29-37.

Control of Larvae of Diamondback Moth

Plutella maculipennis Curtis

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For the last five years the larvae of the diamondback moth, *Plutella maculipennis* Curtis, have been very destructive to cruciferous crops, such as broccoli, cabbage, collards and kale, in the Norfolk trucking district. The injury has been most severe beginning in late August or September and continuing on through November, but in 1932 spring cabbage was seriously damaged.

Walker & Anderson (1934) obtained satisfactory control of this insect in 1933 with derris dusts containing as low as .5 per cent rotenone. However, in 1934 local truck growers complained that they could not control this insect with derris dusts containing .75 per cent rotenone. In response to these complaints tests were conducted in a heavily infested broccoli field, and from 40 to 50 pounds per acre of a derris dust containing .75 per cent rotenone were required to control this pest (Walker & Anderson 1935). Single applications of 30 to 35 pounds of this dust per acre did not kill 50 per cent of the worms present in the field at the time of treatment.

To determine the cause for the wide variation in the results obtained in 1933 and 1934, an experiment was conducted on infested collards in the fall of 1935 in which a derris dust was applied with a traction duster at the rate of 25, 35 and 50 pounds per acre. The derris dust used in this

experiment was made by diluting a finely ground derris powder, supposed to contain 5 per cent rotenone, with talc to .75 per cent rotenone content. Later analysis of a sample of this derris powder showed that it contained 2.19 per cent rotenone and 9.82 per cent total extractives, thus the actual rotenone content of the dust used was .33 per cent.

The collards were dusted October 22 and 29 and November 11 on calm quiet afternoons between 3:30 and 5:30. Records were taken of the number of larvae present on 18 plants from each treatment October 24 and November 5 and on three plants October 28. These data are given in table 1 as the average number of larvae per plant. In taking these records it was noted that the young newly hatched larvae were very susceptible to derris, but that they became more and more resistant to it as they grew older. Many of the nearly full-grown larvae were able to survive and complete their development, even where the dust had been applied at the rate of 50 pounds per acre, whereas nearly all of the newly hatched larvae were killed with the 35-pound application and many were killed with the 25-pound application.

Table 1.—Dusting collards with derris dust containing about .33 per cent rotenone for control of larvae of the diamondback moth in 1935.

Rate of Application	Average Number Larvae per Plant		
	Oct. 24	Oct. 28	Nov. 5*
50 lbs. per acre	8.	4.7	3.
35 lbs. per acre	6.	9.7	4.3
25 lbs. per acre	8.5	19.3	10.7
Check	*15.2*	*23.3*	*21.9*

* A difference of 3.5 may be considered statistically significant.

A study of the larval counts made on October 24 and 28 as given in table 1 shows that about 80 per cent control resulted within six days from the first application of dust on the plats receiving the 50-pound application, 59 per cent on the 35-pound application, and 17 per cent on those receiving the 25-pound application.

On November 5, seven days after the second application of dust, good control had been obtained with the 35 and 50-pound applications and there was practically no difference between them. The 25-pound application of dust reduced the larval population about 50 per cent but enough worms were left to injure the plants seriously.

Later, a few young larvae began to appear on the plants and a third application of dust was made on November 11. This dusting protected the plants for the rest of the season where the 35 and 50 pounds of dust were applied, and a good crop of prime collards was harvested the latter part of December. The collards on the untreated or check plats and on the plats dusted at the rate of 25 pounds per acre were seriously injured and produced a very poor quality crop.

This test indicated that the nearly full-grown larvae of the diamondback moth are resistant to derris dust but that the newly hatched larvae are susceptible, and that repeated applications of derris dust containing .33 per cent rotenone at the rate of 35 pounds per acre at seven to 10-day intervals will kill the young worms as they hatch, resulting in good control. The resistance of the nearly full-grown larvae probably accounts for the poor control obtained with derris in 1934, as a large percentage of the larvae were nearly full grown at the time the dusting was done.

An experiment was conducted on collards in the fall of 1936 to test

further the value of derris for the control of the larvae of the diamondback moth and to compare it with *Noburn*, cubé, a stabilized derris, and a mixture of derris and pyrethrum. *Noburn* is the trade name for an arsenical dust containing not less than 10 per cent Paris green and 40 per cent calcium arsenate plus an inert carrier. The derris and cubé used in this and succeeding experiments contained 5.2 per cent rotenone and 19.1 per cent total extractives, and 4.9 per cent rotenone and 22. 1 per cent total extractives respectively. In this experiment these dusts were used

Table 2.—Results of dusting collards for control of larvae of the diamondback moth on September 14, 28, October 6 and 31, 1936.

Dusts	Population Counts, and Dates						
	Larvae 9/17	Larvae 9/28	Larvae 10/2	Larvae 10/12	Pupae 10/12	Larvae and Pupae 10/12	Larvae 11/10*
Noburn	2.	57.	6.	5.3	3.3	8.7	40.7†
Derris–talc	4.8	43.7	16.5	6.2	10.7	16.8	7.1
Cubé–talc	4.1	55.5	12.3	3.5	4.3	7.8	8.
Derris–pyrethrum–talc	5.	31.	13.2	3.	5.2	8.2	5.6
Stabilized derris–talc	4.3	47.2	26.5	13.7	21.7	35.3	33.8
Check	*10.9*	*73.2*	*125.7*	*84.2*	*141.8*	*226.*	*115.8*
Significant difference	2.8		9.3	5.8	3.4	8.6	11.7

* Counts on November 10 are based on the average number of larvae on five leaves; counts on other dates are based on an average for three plants.

† *Noburn* was not used in the last treatment because of the danger of an arsenical residue, and the counts in the last column should not be used in comparing the insecticidal value of *Noburn* with the other dusts.

at the rate of 15 parts of cubé or derris to 85 parts by weight of talc to produce a dust containing approximately .75 per cent rotenone. These dusts were applied to six-row plats replicated three times at the rate of 20 to 25 pounds per acre on September 14, 28, October 6 and 31.

Records were taken by walking about one-third of the way across the field, counting off 10 consecutive plants and then counting and recording the number of larvae remaining on the first, sixth and eleventh plants in the second and fifth row of each plat. A similar count was made on October 12 except that the number of pupae was also recorded. The plants had become so large by November 10 that samples of five leaves were substituted for the three plants by counting the larvae on one leaf from every fifth plant. These results are given in table 2 as an average of the number of worms present on three plants or, in the November 10 count, five leaves, together with the difference required for one material to be considered statistically different from any other. It was found that the checks contained such large numbers of larvae that these counts had to be omitted in making the statistical analysis in order to measure differences between the other treatments. The counts on September 28 were made just before the second application of dust and were so variable that none of the differences were found to be significant, indicating that the first dusting had lost its effectiveness. There were rather definite life cycles of this pest in this field, the peak of a new brood of larvae hatching from about September 19 to 24. These larvae were becoming full grown and pupating from October 5 to 10. Then there was a period

when practically no injury occurred and the plants rapidly outgrew the effects of this feeding until a new brood of larvae began hatching the latter part of October. This brood of larvae ruined the market value of all the undusted collards in this field. An idea of the severity of this reinfestation may be obtained by noting that where *Noburn* was not used in the last application of dust on October 31 the larval population had built up to an average of 40.7 larvae per five leaves on November 10.

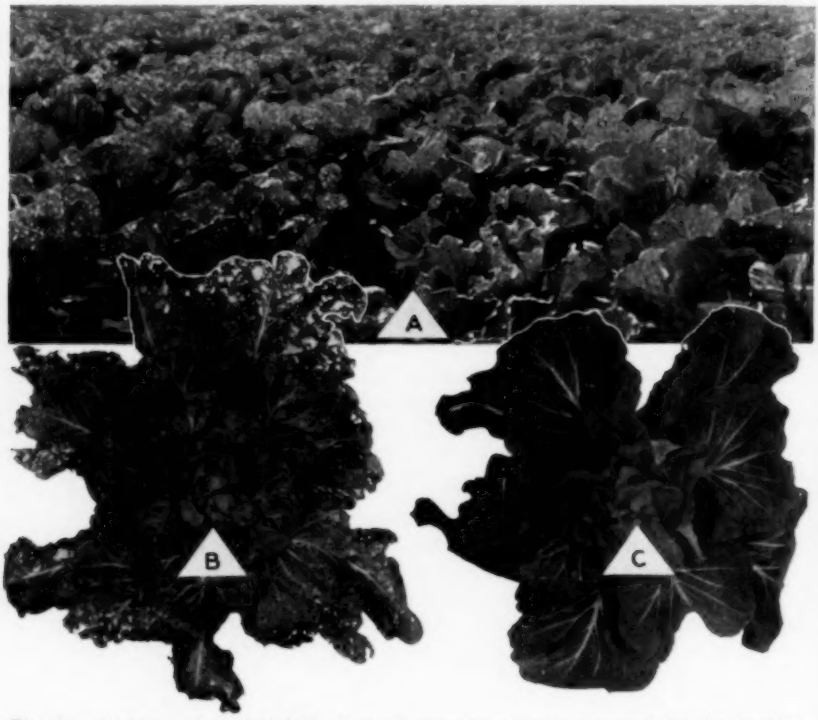

Fig. 1.—*A*, View of collard field showing severity of injury caused by the feeding of larvae of diamondback moth on undusted plants on the left, as compared with dusted plants on the right; *B*, Close-up view of an undusted plant; and *C*, close-up view of a plant taken from the plats dusted with cubé.

In this experiment the derris, cubé and derris–pyrethrum dusts gave satisfactory control of the larvae of the diamondback moth and a fine crop of good quality collards was grown on the plats dusted with these materials. The *Noburn* gave very satisfactory results until its use was discontinued on October 6 because of the danger of a high arsenical residue if used at a later date. The stabilized derris dust did not give satisfactory control. The untreated or check plats were very seriously injured and produced a poor crop of unmarketable collards. The severity of this infestation and the benefits that were derived from dusting are illustrated in fig. 1. The four applications of derris, cubé, and derris–pyrethrum dusts protected the plants throughout the growing season

even though the check plats and the surrounding fields were heavily infested and produced large numbers of moths which continued to lay eggs in the dusted as well as in the undusted plats until the latter part of October or first of November.

A similar experiment was conducted to determine the value of different arsenical, cubé and derris dusts to control the diamondback moth on kale. The dusts were applied with a traction duster to three-row plats, replicated four times, on October 13, 20 and 31. All of the dusts were applied at the rate of 20 to 25 pounds per acre, except *Chalk Mixture*, which was applied at the rate of about 50 pounds per acre. Records were taken October 19 of the number of larvae surviving on 30 leaves from the plants treated with each dust and from the untreated checks, and on October 23 of those remaining on 40 leaves, in the same manner as for records taken in the collard experiment.

Table 3.—Results of dusting kale on October 13 and 20, 1936, for control of larvae of the diamondback moth.

Dusts	Per Cent Rotenone Content	Average No. Larvae Present on Five Kale Leaves	
		October 19	October 23
Noburn		18.8	3.9
Chalk Mixture		30.5	8.4
Calcium arsenate–hydrated lime, 1:1		18.5	5.1
Derris–*Aresket*–talc	.75	32.	6.5
Cubé–*Aresket*–talc	.75	31.5	5.1
Cubé–*Aresket*–talc	.50	29.8	8.5
Cubé–talc	.75	24.8	7.6
Cubé–talc	.50	31.8	12.
Check		*38.3*	*30.1*
Significant difference		13.1	7.

The dusts used, control obtained expressed as the average number of larvae surviving on five leaves, and the difference required to be significant between the larval populations of any two treatments are given in table 3. *Chalk Mixture* was a cheap low-grade arsenical dust. The calcium arsenate–hydrated lime mixture contained 50 per cent by weight of calcium arsenate. The *Aresket* (alkylated sulfonated diphenyl) was used at the rate of 1:600 parts by weight of the derris or cubé–talc mixtures. It may be noted that the first two applications of dust resulted in from 70 to 85 per cent control, with all but the cubé–talc dusts containing .5 per cent rotenone. In these tests, the dust containing *Aresket* gave slightly but not significantly better results than did similar dusts without it. The three applications of all of the dusts used in this experiment prevented serious injury by the larvae of the diamondback moth.

As a result of these tests, kale plants infested with newly hatched larvae of the diamondback moth were dusted on October 31 and November 10 at the rate of about 25 pounds per acre with derris–talc and cubé–talc dusts containing .5 per cent rotenone, both in combination with and without *Aresket*. The derris–talc, derris–*Aresket*–talc, and cubé–talc dusts gave 82 per cent control and the cubé–*Aresket*–talc dust gave 87 per cent control, indicating that there is very little difference between the effect of any of the dusts and that if applied when the larvae of the diamondback moth are young, either a derris–talc or a cubé–talc dust containing approximately .5 per cent rotenone and 2 per cent total extractives will give satisfactory control of this insect.

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The Hollyhock Thrips

Liothrips varicornis Hood

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Of the hundred-odd species of thrips known in California less than 10 per cent are of economic importance as crop pests. Many are doubtless of minor importance and their injury unknown because they have never been studied. Such is the case with the hollyhock thrips, *Liothrips varicornis* Hood.

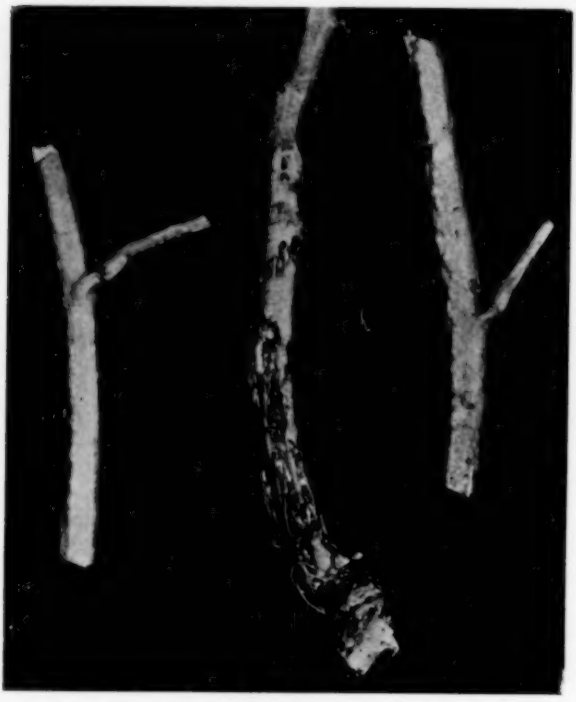

Fig. 1.—Injury to hollyhock by *Liothrips varicornis* Hood. Note pits and scars on main stalk, crown, and in axils of leaf stem and stalk.

This thrips was described by J. D. Hood in 1912 from one female specimen taken in grass and sweepings by Chas. A. Hart at Monterey, Mexico, on July 5, 1908. It is a member of the suborder Tubulifera and the family Phlaeothripidae. Hood (1918) and Watson (1923) merely referred to the above record and the writer has listed it among other California species (Bailey 1935). Essig (1926) wrote concerning the Christmas berry thrips, *Rhynchothrips ilex* (Moulton), "The writer has taken the adults and young on the leaves and stems of tree malva in southern California. It also occurs on hollyhocks" (Bailey 1936). The specimens which Essig collected from Laguna Beach, Calif., on July 1, 1921, are now known to be *L. varicornis* (Bailey 1937). S. B. Freeborn collected this species on hollyhock at Maxwell, Calif., on

April 27, 1936 (Bailey 1937). The first published record of this thrips from California is that of Moulton (1927), who reported it also from hollyhock at Marysville, Calif., in December 1926. Since 1929 the writer has observed it commonly on hollyhocks at Davis (Bailey 1933). Through the kindness of H. H. Keifer of the California State Department of Agriculture the following additional distributional records from hollyhocks in California were obtained: Colusa, Santa Paula, Sutter, Ukiah and Whittier. Among these is one doubtful record of this species from Christmas berry, *Photinia arbutifolia*.

From the above data it can be seen that this thrips is doubtless limited to a semi-arid climate and is found principally on its favorite host the hollyhock.

The injury to the host results from the feeding of the adults and larvae which are gregarious on the stalk, leaves and roots, fig. 1. As a scar or depression is produced by the extraction of the sap from the surface of the stalks, the thrips enlarge the injured area and often penetrate to the hollow center. It is common to find large numbers of larvae feeding on the inside of the stalks. In addition, eggs, pupae and adults have been taken from inside the injured stalks near the ground. The feeding in the axils of the leaf stem and main stalk frequently causes the leaves to wither badly. The roots are often scarred on the surface from the crown down to about four inches below the ground. Plants have not been known to be killed by this insect alone. Leaf-feeding Lepidoptera, particularly the Painted Lady, West Coast Lady and Mourning Cloak larvae, are much more serious pests.

The life history has been worked out on hollyhocks at Davis, Calif. Winter is passed on the roots, chiefly by the adults. In the spring these jet black overwintering individuals move up on to the new growth which often sprouts from the base of the old stalks, or crawl to new, young plants nearby. Pupae have been found outdoors up to December 1 and larvae as late as December 25. Only adults have been known to survive the months of January, February and March. The latter part of March or by the first of April the surviving adults may be seen copulating and crawling about on the crowns or on the new leaves. Egg-laying begins about two weeks later.

The buff-colored eggs, which are covered with a light coating of white wax in the form of irregular, polygonal reticulations, are laid in the angles of the leaf stems and stalks, under the bracts, or in depressions and cracks in stalks and roots. The eggs are oval to bean shape, about .4 mm. in length and the shell is composed of hexagonal sections. On the average, each female lays 10–12 eggs, which are loosely deposited in irregular clusters since this thrips has no ovipositor. The period of egg laying of a colony extends over approximately a month's time. By the last of May all adults have died.

Depending on the weather the eggs hatch in about four weeks but some have remained as long as 37 days in this stage. The larvae are brilliant red with the terminal segments of the abdomen, the head, prothorax, legs and antennae black. The average length of the mature larvae is about 2 mm. Full development is attained in 18–25 days or normally three weeks. When mature, the larvae may, if feeding on the exposed

part of the host, crawl down into the top soil often to a depth of 4 inches. However, if feeding on the roots or inside the stalks, they will pupate in the midst of a colony of immature larvae. Thus all stages are sometimes found clustered together. One molt occurs when the larvae are about half grown and another when maturity is reached. The prepupal stage is thereby attained, and it lasts one to three days. After molting again, the true pupa, slightly less than 2 mm. long, is to be seen with wing pads extending downward along the sides of the abdomen. The pupa is yellow with crimson pigment present on the thorax and abdomen. This so-called pupal stage is mobile but takes no food and makes no cell. After six to eight days the pupa molts to the adult.

By the last of June a few newly emerged adults may be seen feeding around the crown of the plant or in the cracks in the stalk if still green. During the hot weather of July and August activity is greatly reduced. Copulation often takes place on the part of the newly emerged adults before feeding. The sex ratio is about three females to one male. From the time the first adults of the second generation appear there is a certain degree of overlapping of the first and second generations since all larvae of the first brood usually have not matured.

Only a few scattered eggs are laid during the summer and all stages are somewhat shorter than in the spring. The second generation is more irregular than the first and continues through the fall on the meager portions of the host plants that are still succulent or on the roots. A high mortality of the immature stages results from the fall and winter rains and consequently dry years favor the multiplication of *L. varicornis*. No natural enemies have been observed. Although having fully developed wings the adults have never been known to fly. Dispersion, even in very local areas, is slow.

Because of the minor importance of this insect and the short growing season of the host, control measures are hardly necessary. Heavy watering of the soil about the base of the infested plants and destruction of all old stalks and volunteer plants during the fall and early winter appear to be the most practical means of discouraging this thrips. Also, because of its habits and apparently very limited distribution, it is doubtful if it will ever become of any great importance as an economic pest.—4-2-37.

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Lineodes integra Zell., a Potential Pest of Greenhouse Tomatoes

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Lineodes integra Zell. has been recorded as feeding on a number of plants of the family Solanaceae, including tomato, eggplant, potato, pepper and nightshade, but has not been considered a pest of these crops. In 1934 injury to tomatoes in a greenhouse at Bloomington, Ill., was called to the writer's attention. In October 1935, green tomato fruits together with some injured foliage infested with larva of this insect was sent in from a greenhouse at Eldorado, Ill. In the accompanying letter the greenhouse owner stated in part: "As long as the insect larvae stay on the leaves of the plants they cause very little damage, but they get on the fruit just under the sepals at the stem and eat holes there or sometimes atack the leaves that rest on the side of a tomato and eat all the skin off at this point, thus ruining the fruit for market." The damage to the tomato crop appeared sufficient to warrant making a study of its habits and methods of control.

Although we have no records of *Lineodes integra* Zell. occurring outdoors in Illinois, investigation of the infestations at Eldorado and Bloomington indicate that the infestations developed from migration of moths into the greenhouse from outdoor plants. There is a possibility that the Bloomington infestation resulted from an importation of tomato plants from the south, which were grown outdoors during the summer. If this supposition is correct, it would likely be most troublesome on the fall crops of tomatoes.

Nature of injury.—All parts of the tomato plant above the ground level are subject to attack. In our experimental greenhouses at Urbana, tomato plants that had set their third cluster of fruit were killed outright unless control measures were applied.

The larva feeds on the leaf, at first skeletonizing, and later eating holes in it, or devouring the entire leaf, leaving only the petiole. The petiole may also show feeding scars. As the larva matures, the edges of the leaf may be cut and tied over or rolled much the same as the injury caused by the greenhouse leaf tier, *Phyctaenia rubigalis* (Guen.) on chrysanthemums. Figure 1, A, shows typical leaf injury.

The surface of the main stem and branches is frequently attacked as shown in fig. 1, B. In addition, the pedicels supporting the fruits are eaten into or girdled. This later injury causes a reduction in the size of the fruit and occasionally the pedicel breaks under the weight of the fruit.

The fruit is attacked in all stages of its development from the time the buds are formed until the fruit ripens. In most cases the larva attacks a fruit beneath the sepals as shown in fig. 1, C. The fruit may also be attacked at the point where it comes in contact with another fruit or the foliage. As the larva matures, feeding continues over the surface until large areas are eaten away. Feeding for the most part is confined to the surface of the fruit, fig. 1, D. The larva does not bore into the fruit

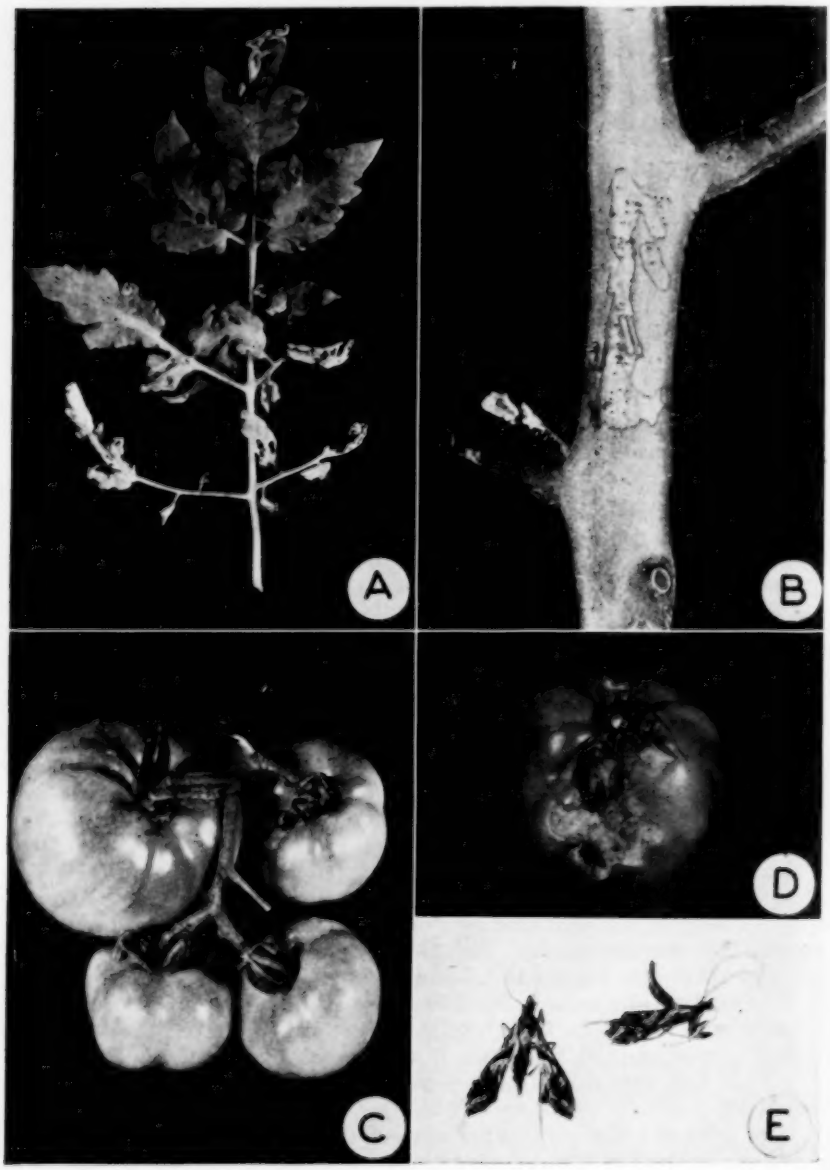

Fig. 1.—Injury to greenhouse tomatoes caused by *Lineodes integra* Zell. A, typical leaf injury; B, injury to the main stem and branches; C, feeding scars on tomatoes beneath the sepals; D, feeding scars on the surface of one fruit at the point of contact with another; E, adult moth, enlarged about three times.

in the manner exhibited by the corn ear worm. All fruits attacked are rendered unfit for market.

Life history and habits.—The adult as shown in fig. 1, E, is rather strikingly colored with black, white and grays. The moth is somewhat smaller and the wings are narrower than that of the greenhouse leaf tier. They are active at sundown and mate and oviposit during the night. During the day they remain at rest on the plants, benches, greenhouse supports and side walls, where they are not easily disturbed. Their habit of elevating their abdomen, which is recurved toward the anterior end, is characteristic of their resting position and is sufficient to distinguish them from other common leaf tier and leaf roller adults. The side view of the specimen in fig. 1, E (enlarged about three times), shows the approximate position of the abdomen when at rest. Ten females in wire cages in the greenhouse deposited 21 to 79 eggs each, averaging 62 eggs per moth.

The eggs are deposited singly or in groups of two to four or more on the undersides of the leaves, on the sepals, and even on the stems. They are round, flat and semitransparent, and they hatch in tomato house temperatures in seven to 10 days.

The young caterpillar upon hatching feeds as a skeletonizer on the undersides of the leaves. During the period of development five larval stages were observed. Under greenhouse laboratory conditions the larvae moulted after approximately equal feeding periods of five to seven days. The mature larva is slender, cylindrical, and tapers slightly toward both ends. The green body is sparsely clothed in fine hairs. They closely resemble the larvae of *Phlyctaenia rubigalis* (Guen.) although the middorsal striping is less pronounced and they are slightly smaller. The length of the fully grown larva is 14–16 mm. The larva when disturbed become very active and move backward and forward readily, often descending from the plant on a strand of silk.

When mature the larva rolls or ties the edge of a leaf to provide shelter for pupation. Pupation may also take place in a lightly constructed cocoon in the stem axils or in cracks and crevices in the stem. Pupation has not been found to occur off the plants.

The pupa are relatively long and narrow, dark brown, and may be distinguished from the pupa of other leaf rollers and tiers found in the greenhouse by the long sheath enclosing the antennae and galea, which extends to or slightly beyond the tip of the abdomen. The average length of the pupa is 9–11 mm. From eight to 12 days are spent in the pupal stage. Six to seven and one-half weeks were required to complete a life cycle in the greenhouse at tomato-growing temperatures, *i.e.*, night, 65–70° F; cloudy day, 70–75° F; bright day, 75–80° F. Starting with eggs deposited on October 21 in the greenhouse, three complete generations and a partial fourth occurred before the tomato crop was finished in the spring.

Control.—Three applications at eight to 10-day intervals of a dust composed of 85 parts by weight 300-mesh dusting sulfur and 15 parts by weight lead arsenate have given excellent control. This dust may be used with safety when an infestation is discovered before the first cluster of fruit is much over half developed. Use of arsenicals after the fruit begins

to mature necessitates washing to remove arsenical residue. Usually the infestation is not discovered until somewhat later when there are serious objections to the application of arsenicals.

Greenhouse tests were made with a .5 per cent rotenone dust composed of 10 pounds of ground derris root having a rotenone content of 5 per cent and 90 pounds of talc. This dust was quite effective in holding the insect in check, but did not give so complete control as the 85:15 sulfur–lead dust.

A proprietary insecticide, *New Evergreen Spray*, containing 6 per cent pyrethrum extractives, was used at a dilution of 1:300. This spray was effective in killing all larvae which were thoroughly wet with the spray solution. Because of the difficulty of hitting larvae in protected places and lack of residual effect the results were not as satisfactory as with the dusts. The pyrethrum spray is more expensive than the dusts.

Many of the adults rest on the glass and greenhouse supports during the day where they can be quite easily hand picked and destroyed.

Summary.—*Lineodes integra* Zell., which has not previously been recorded as a pest of tomatoes, is capable of causing severe damage to this crop as grown in the greenhouse. All parts of the plant above ground are subject to attack. The principal damage is caused by feeding of larvae on the fruit. The larva closely resembles the larva of the greenhouse leaf tier, *Phlyctaenia rubigalis* (Guen.). The larva, pupa and adult, however, can be readily distinguished from the corresponding stages of the greenhouse leaf tier.

A sulfur–lead dust made up of 85 parts by weight of 300-mesh dusting sulfur and 15 parts by weight of lead arsenate gave the most satisfactory control. Arsenicals are not recommended when the fruit is ripening unless the fruit is to be washed. A derris dust containing .5 per cent rotenone with talc as a diluent gave commercial control under greenhouse conditions. A pyrethrum spray containing 6 per cent pyrethrum extractives was effective in killing all larvae thoroughly wet with the spray. The expense was greater than with the dusts. Hand picking the adults is an aid to control.—4-23-37.

White Coating on Foliage a Repellent for Potato Leafhopper

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In connection with experimental work on the control of insects upon dahlia it became apparent that the potato leafhopper, *Empoasca fabae* (Harr.), was repelled by a white coating on the foliage. Experiments showed that while certain white commercial dusts did not kill the insects, they did afford protection (McDaniel 1936) just so long as a layer of white residue remained on the plant. In following up these observations,

[1] Journal article 279 n.s. Acknowledgment is given to Professor Ray Hutson for valuable suggestions; to Frank Parmelee for his conscientious work as field assistant; to the Department of Farm Crops, Michigan State College, for the privilege of using their experimental plots on alfalfa and potatoes and to Otto Hoeppner for his generosity in donating his large dahlia field for experimental purposes.

several untreated dahlia plants of particularly susceptible varieties were dusted respectively with infusorial earth, talc and flour, three white inert materials commonly used as carriers in dusts. Two applications were made; one August 28, the other September 15. The leafhoppers immediately deserted the dusted plants and did not re-establish themselves on them. The dusted plants put out new growth, developed rapidly and produced a good crop of flowers. As nearly as could be ascertained there was no difference in the effectiveness of the three dusts and any one was just as effective as the commercial contact dusts. Undusted plants of the same variety remained infested until the plants were frosted. No new growth developed and no flowers were produced.

To demonstrate further that a white coating repelled the potato leafhopper a series of experiments was conducted in 1936, using three choice host plants of the potato leafhopper: alfalfa, dahlia and potato.

Table 1.—Number of potato leafhoppers present 24 to 48 hours after dusting.

	Counts Made				
	July 21	July 30	Aug. 6	Aug. 12	Total 4
Flour	58	31	17	23	129
Lime	46	34	13	11	104
Talc	39	40	22	17	118
Check	117	96	87	49	349

Alfalfa.—For several years the Department of Farm Crops at Michigan State College has been conducting experiments to determine the effect of early and late cutting with respect to the yield per acre. Each season the main purpose of this experiment has been defeated because the leafhopper invariably migrated from the newly cut alfalfa to the field of standing plants and in many instances either stunted the plants to the place where the results were worthless or visibly affected the yield.

To check this migration, in 1936 the uncut alfalfa was protected by a 20-foot barrier of hydrated lime at 30 pounds to the acre. In placing this barrier no consideration was taken of an unprotected alfalfa-seed nursery across the road. The barrier was laid July 3 and the field was cut July 6. The leafhoppers deserted the cut alfalfa and settled on the unprotected plants in the nursery.

On July 18 it was discovered that the leafhoppers were deserting the nursery plants and migrating around the barrier to reach the protected field. On July 20 a series of barriers, including flour, talc and lime, in replications of three, was laid between the nursery and the protected field. Four applications (July 20 and 28 and August 5 and 11) were necessary to keep the barrier effective. These applications were made when required—for example, after a heavy rain—rather than at stated intervals. All barriers proved effective and in no instance did the leafhoppers get past barriers in sufficient numbers to become an economic factor on the protected plot.

Table 1 shows the relative value of the three barriers. The counts were based on 50 sweeps of a 12-inch net.

July and August 1936 were dry and by the middle of August most of the leafhoppers had deserted the alfalfa (Smith & Poos 1931) and located

on more succulent plants. Following a heavy rain on August 22 rank new growth of alfalfa developed, and the leafhoppers again became numerous in the field, but not in sufficient numbers to cause any evident loss.

The increase in the yield per acre could not be determined from these plots because other plots used as check were grown under different conditions, but the falfalfa in the protected field remained green throughout the summer and had only a light infestation of leafhoppers while surrounding fields turned yellow (Fenton & Hartzell 1923) and contained many leafhoppers until about August 15.

Dahlia.—In 1936 the experimental work on potato leafhopper infesting dahlias was reduced to two items. Half of a large dahlia field containing a large number of varieties was dusted with hydrated lime, the other half with flour; 15 check plants, consisting of varieties particularly susceptible to the potato leafhopper, were left in each plot.

Table 2.—Yield per acre in dusted and undusted plots.

Variety	Yield in Bushels per Acre			
	Flour	Lime	Talc	Check
Irish Cobblers	351	375	370	322
Katahdin	382	429	393	411
Rural Russet	390	359	423	391
Burbank	357	297	289	284
Chippewa	394	328	456	387

The potato leafhopper population in this field at no time compared with that of 1935. In 1935 the dahlia field was surrounded by fields of alfalfa, beans and clover, and there were many weeds along the edges of the field. In 1936 the field was surrounded by crops belonging to the grass family, and no weeds were in the field nor along the edges. Also the plants were slow in developing in 1936, due to the dry weather and to the intense heat. The first infestation of leafhoppers occurred about August 1. A number of alfalfa leafhoppers, *Agallia sanguinolenta*, were also present. The plots were dusted August 3 and 15. Both species of leafhoppers were repelled by the dust.

Since it was impracticable to make sweepings on dahlia plants, the results were determined from the appearance of the checks examined September 10. Five of the untreated plants in the flour plot and three of the plants in the lime dust plot did not produce flowers. All plants in both checks were stunted and all carried an unusually heavy infestation of leafhoppers, since a large percentage of leafhoppers from the treated plants surrounding the checks congregated here rather than staying on the dusted plants. A heavy rain August 22 followed by cool weather was not conducive to the development of a late brood of leafhoppers but was ideal for dahlias and although many leafhoppers were present throughout the field after September 10, no damage was apparent. On September 10 all checks were dusted with hydrated lime and when examined September 15 the leafhopper population was considerably less than that of adjoining plants and rank new growth developed on all check plants dusted.

Of the two dusts, lime was the most satisfactory as it went on most smoothly and adhered to the plant for a week to 10 days longer than flour.

Potato.—The experiments with dusts as repellents against the potato leafhopper on potatoes were conducted on experimental plots belonging to the Department of Farm Crops. The plants were grown on sandy soil and did not suffer from the dry weather since they were watered all summer with a portable sprinkling system.

This plot consisted of three rows each of five common varieties, Irish Cobbler, Katahdin, Rural Russet, Burbank and Chippewa.

To determine the relative effectiveness of flour, lime, talc and sulfur as repellents for the potato leafhopper, this large plot was subdivided crosswise, so as to have three rows of each of the five varieties in the treated plot. Each plot was a rod wide and there were three replications for each ingredient used, besides a check plot 4 rods wide. The first leafhoppers appeared in the plots about July 1. The first dust was applied July 7, the last September 12. The results of these applications were required, because the overhead sprinkling system moved gradually back and forth across the field all summer and as soon as a plot dried it was necessary to re-dust. Sulfur was discontinued after the first application because there was evidence of some burning. In the succeeding applications the sulfur plots were used as checks.

Plots dusted with lime and talc were in the best condition at the end of the season and there was no evidence of hopper burn on any potatoes in the dusted plots, though considerable was apparent in all the checks. Dusted plots yielded 23 bushels per acre more than check plots.

To determine the relative degree of repellence for each of the three dusts, sweepings were made 24 hours after each application. A 12-inch net was used and 50 sweepings were made each time in each plot. There were consistently fewer leafhoppers in the plots dusted with lime throughout the season; talc ranked next in efficiency and flour ranked third. The check contained twice as many leafhoppers as the plots dusted with flour.

Summary.—Field experiments conducted in 1935 and 1936 on dalia, potato and alfalfa show that the potato leafhopper, *Empoasca fabae*, is repelled by a white coating on the foliage.—5-27-37.

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Host plants of the peach mosaic disease may be shipped out of infected counties in Colorado only on condition that the plants and budding wood have been produced on premises having a disease-free radius of 5 miles for at least a year, as determined by competent inspection prior to June 30 each summer, according to Colorado "Standard State Quarantine Order No. 1," as revised March 15, 1937. A similar standard is required in quarantines placed by Arizona and California with respect to intrastate and interstate movement.

Dissemination of Insects by Air Currents

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Appearance last year of the European spruce sawfly, *Diprion polyotomum* Hartig, in widely separated New England and northern New York state localities, the undoubted wind spread of small gipsy moth caterpillars, *Porthetria dispar* Linn., a presumably more limited wind spread of young fall cankerworms, *Alsophila pometaria* Harris, discovery the past season of general and well separated infestations of the apple leaf-curling midge, *Dasyneura mali* Kieff., and the distribution picture of the beetle-carried Dutch elm disease in the states of New Jersey, New York and Connecticut, have aroused interest in air currents as disseminators of insects. This is here considered primarily a question of wind drift rather than of casual or purposive flight.

Presumably no question would be raised if the sudden appearance of the European spruce sawfly in the northeast were attributed to wind currents. The enormous production of adults on the Gaspe peninsula at a time when conditions tempted the insects into the air seems the most satisfactory explanation of the wide distribution of this sawfly.

It is known that young gipsy moth caterpillars are carried considerable distances by wind currents and conditions in southwestern New England in particular have justified in the last few years an opinion that wind spread of small cankerworms may be more general and considerably wider than had been suspected previously.

The sudden appearance in well separated localities of the apple leaf-curling midge reported the past summer by Professor W. D. Whitcomb of the Massachusetts Field Experiment Station, Waltham, can best be explained by drifting with wind currents. In these instances presumably millions of the tiny midges were produced at a time when conditions were favorable to flight and as a result hosts of the insects were carried to various orchards. Similar conditions were obtained in our balloon work the past season, *e.g.*, there were three returns from Center Moriches on the south shore of Long Island, 43 miles from the point of release. Two of the balloons were found on the same farm and within 60 rods of each other, although one was released 16 days earlier than the other.

Our balloon records of the summer of 1936 are most suggestive when studied in connection with the known distribution of the Dutch elm disease and with the assumption that a considerable proportion of the diseased trees in the northeastern area were infected by the smaller European elm bark beetle, *Scolytus multistriatus* Marsh, and that consequently most of the diseased trees located record insect drift from some center of infection, presumably an area where a large number of elms have been attacked by this disease.

There were released 4935 balloons between May 9 and July 23 from Maplewood (67), Morristown (100) and West Orange (198), N. J., Amenia (36), Peekskill (54), Pelham (108) and Yonkers (131), N. Y. and Cornwall (67) and Stamford (4174), Conn.

The need for establishing a basis of operations in a study of this nature is evident. The major spread (not necessarily the initial spread) of the Dutch elm disease in the early days must have been from an area where there were large numbers of diseased trees producing millions of the carriers. There is a record of 315 diseased trees being found in Essex county, N. J., in 1933 with relatively very small numbers in Union (11), Passaic (7), Bergen (4), Hudson (4) and Somerset (1) counties. The same year diseased trees were found on Staten Island, in Brooklyn, in Nassau county at Port Washington and Lynbrook and in Westchester county at Rye and one diseased tree in western Greenwich, Conn. Taking Essex county, N. J., as the approximate center of what may be termed general dissemination, the record for 1933 shows scattering diseased trees, some 35 to 40 miles from this assumed center of distribution. The 301 balloons released June 1 and 3 from West Orange and Maplewood, N. J., resulted in the return of one tag from Glen Cove, L. I., a location about 5 miles from where the Port Washington elm was found. The return of a tag from the Bronx and one from Shelton, Conn., are both in a nearly direct line to the 1933 diseased trees found in Rye, indicating an unmistakable drift over an area which subsequent exploration showed to be somewhat badly infected by the disease. The 100 balloons released May 15 at Morristown, N. J., resulted in four recoveries on western Long Island in a fairly straight line, namely Long Island City, Queens Village, Bellerose, South Farmingdale, Oakdale (60 miles) and one at Westhampton Beach, some 82 miles from the point of liberation. In the releases from these three localities we have an evident concentration of returns within 35 or 40 miles with occasional recoveries up to a distance of 60 or 80 miles. A similar distribution is seen in the 131 balloons released June 18 at Yonkers, N. Y., the recoveries being from Danbury to Avon, Conn., a range northeasterly of approximately 35 miles and one balloon at Amherst, Mass., a drift of 118 miles. The general picture of the releases from these four localities indicates an easterly and in the case of Yonkers a northeasterly drift from the assumed center of distribution, Essex county, N. J. A similar trend in the spread of the disease is supported by the record of 74 affected trees in the Bronx, 450 from Westchester county and 92 from the western end of Long Island by July 24, 1934.

The record of the 3,321 released at almost daily intervals at North Stamford Conn., from May 9 to June 13 is of exceptional interest for New England localities. Here, as in the case of the Yonkers and Morristown balloon releases, there were returns from a few remote places, namely, Rochester, Vt., Upton and Boston, Mass., 183, 117 and 147 miles respectively, and Westerly, R. I., approximately 75 miles. A particularly significant feature is that of the returns from places 40 miles or more from North Stamford, 16 were from New England, a northeasterly drift, and 24 from the south shore and western end of Long Island, a southeasterly drift. These figures suggest that a considerable percentage of the balloons must have been carried out to sea as shown by the large number (12) recovered on the south shore of Long Island and the return of one tag from off Nantucket lightship, a distance of possibly 180 miles. The losses at sea may have run as high as 20 per cent. An encouraging feature is that presumably many drifting smaller Euro-

pean elm bark beetles were likewise carried to sea and the percentage of such disasters, if they can be so considered, would be decidedly greater from Essex county, N. J., the assumed center of distribution, because even easterly drift from there is toward the ocean. There is a note of interest in connection with the three balloons recovered at Center Moriches on the south shore of Long Island. Two were from the same farm and within 60 rods of each other, although the liberations were 16 days apart and the place of release 43 miles distant.

There was a marked extension of balloon drift from the North Stamford liberations along the north shore of Long Island sound. It is quite suggestive of the distribution indicated by the finding of trees affected by Dutch elm disease two years ago at Old Lyme, Conn., and the past season at the intermediate localities of Branford and Guilford, Conn. One balloon was returned from Sound View close to Old Lyme and two from Guilford. A marked concentration of balloon returns from the southwestern shore of Connecticut and scattered finds farther east agree almost exactly with the occurrence of trees affected by the Dutch elm disease. There is an evident connection between the number of diseased trees and the distance from the assumed center of distribution. A record of diseased trees found in Connecticut eastward from New York is as follows: Greenwich 133, Stamford 45, Darien 24, Norwalk 13, Westport 4, Fairfield 2, Branford 1, Guilford 1, Old Lyme 6; the approximate distances being respectively 36, 40, 43, 47, 52, 56, 70, 75 and 87 miles. The one anomaly is the six diseased trees found at Old Lyme, but since the infection was found in 1934, it was not surprising that there has been some local spread—they may have been reinfections via the air route. The conditions suggest that the Branford and Guilford infections found this season are recent, possibly very recent.

Naturally there is some question in relation to balloons drifting such great distances within a reasonable period and the possibility of similar movements of insects. The probability of extended drift by either a balloon or an insect is indicated by the returns the past season from 30 balloons found the day they were released. Six of these drifted over 30 miles an hour and five 25–30 miles an hour, the average for the former being 39 and for the latter 26 miles per hour. These figures are relatively moderate compared with drifts of 65 and 100 miles an hour obtained in the balloon work of the New York State Conservation Commission in 1923 and 1924. The sudden appearance of the Mexican bean beetle, *Epilachna varivestis* Muls., in western Connecticut and portions of western Massachusetts in 1929 is at least strongly suggestive of extended wind drift since this southwestern insect presumably must have traveled 75 to 100 miles or more from the earlier infested New Jersey points. It has been stated by some that the smaller European elm bark beetle is too heavy an insect for protracted flight or drift and it is presumable that most of these insects establish themselves in relatively nearby trees. It is the exceptional ones aided by unusually favorable air currents in which we are particularly interested. There are records of Ambrosia beetles and bark beetles being taken in airplane traps by agents of the federal Bureau of Entomology, as it was then known, at elevations of 2000 feet, 500 feet and 200 feet, in Louisiana, all of these insects being

approximately of the same size and weight or even heavier than the European elm bark beetle. It is easy to see that a 30–50 mile breeze would do the rest. Dr. A. D. Hopkins, an outstanding authority on bark beetles, who made a close study of the outbreak of the southern pine beetle, *Dendroctonus frontalis* Zimm., in the early 90s, has stated that it appears from a general estimate that some of the great swarms of this insect must have covered distances of more than 100 miles. These records, in connection with the justified assumption that most of the diseased elms in the northeastern United States were infected by beetles which must have issued or fed upon diseased trees, warrants the belief that the somewhat distant spread is due to wind drift. Incidentally, this in connection with the marked southeastward drift of balloons along the south shore of New England suggests a reason for the relatively slow progress the *Scolytus* is making toward the area in eastern New England now infested by this insect, but from an earlier and independent introduction discovered about 1909 at Cambridge, Mass.

The location of the Branford and Guilford trees about mid-way between the earlier discovered cases at Fairfield and Old Lyme, Conn., establishes the probability of dissemination of the disease over distances of 14 to 20 miles, and probably more, unless one is prepared to admit that undiscovered cases occur both east and west of these trees and have existed long enough to permit secondary spread. This latter, as in the case of the Old Lyme trees, should result in some nearby diseased elms. All things considered, it is believed that wind carriage of infected beetles affords the most reasonable explanation of the distribution of the Dutch elm disease in the northeast and that the balloon distribution data obtained the past season indicates the general lines of further spread, which latter is bound to continue so long as diseased trees continue to produce beetles.—1-7-37.

Use of Illustrative Material in Presenting Subject Matter

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The greatest problem of the program committee in recent meetings has been to accommodate all the papers and still permit the authors sufficient time properly to cover their subjects. It would appear therefore that more time will need to be spent by the authors in analyzing and summarizing the data so that they can be presented in abstract form. The few people who are interested in the details may make direct contacts with the author.

In presenting a paper, there are certain tools which can be used to help the speaker clarify his remarks. It must be remembered that people learn by what they see, by what they hear, or what they take part in. Each individual possesses all of these characteristics, but one is usually dominant. Judging by the tools used in modern advertising, the public takes heed of what they see. Merchants exhibit their wares whenever and

wherever possible, and follow those displays with pictures. They realize that one picture tells more than columns of descriptive matter. We entomologists are directed in our purchases by modern advertising, so why shouldn't we use some of the same tools in displaying our wares? In meetings people are too prone to rely on the spoken word when an exhibit, chart, lantern slide or film strip might reduce the amount of discussion necessary.

Incorrect use of exhibits.—With reference to exhibits, anything which is large enough to be seen from all parts of the hall can be exhibited at the time the speaker is discussing it. The exhibit should then be placed

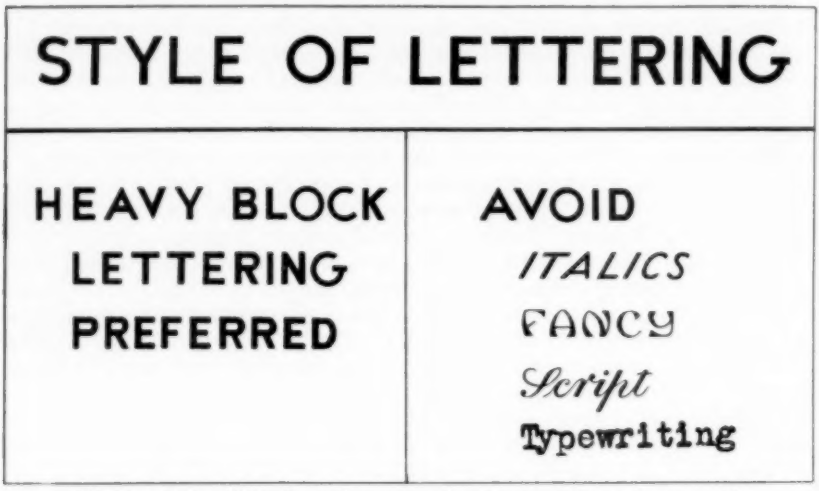

Fig. 1.—Style of lettering to be preferred and some of the styles to avoid.

out of sight. It is a mistake to pass around during the discussion a series of photographs or small exhibits. They most certainly distract the attention of the audience. As an example: if a person talking to 100 people passes around 10 pictures, it is certain that 10 per cent of his listeners may just as well have left the room. In addition to these 10, the persons on the left of each of these attempt to get one last look at the picture, and the persons to the right, and possibly to the rear of them, attempt to get a preview. As a result, the speaker has lost about 40 per cent of his audience. In other words, when we take into account all the disruptions, the speaker has invited almost half the people to leave while he is talking. Too often the following speaker is obliged to talk to absentees due to those same pictures. Exhibits of the smaller type should be placed on exhibition in the space provided for them.

Lantern slides and charts.—Lantern slides and charts afford a very satisfactory means of presenting subject matter, providing they are properly prepared.

The following suggestions offer in a brief way, points to be considered in making and presenting lantern slides.

Size of Projected Image.—It appears that an image approximately

5 by 6 feet, projected from a lantern slide, is the average size for most meetings. If the slide has been properly made, the text will be visible the full length of a large hall. By planning for an image of this size, it is easy to arrange a desirable screen. If it is necessary to use a screen much smaller than 4 by 5 feet, the image is too small to be plainly visible. Assuming the field of a slide to be $2\frac{1}{2}$ by 3 inches, the enlargement will be about 24 diameters when projected to an image of 5 by 6 feet on the screen.

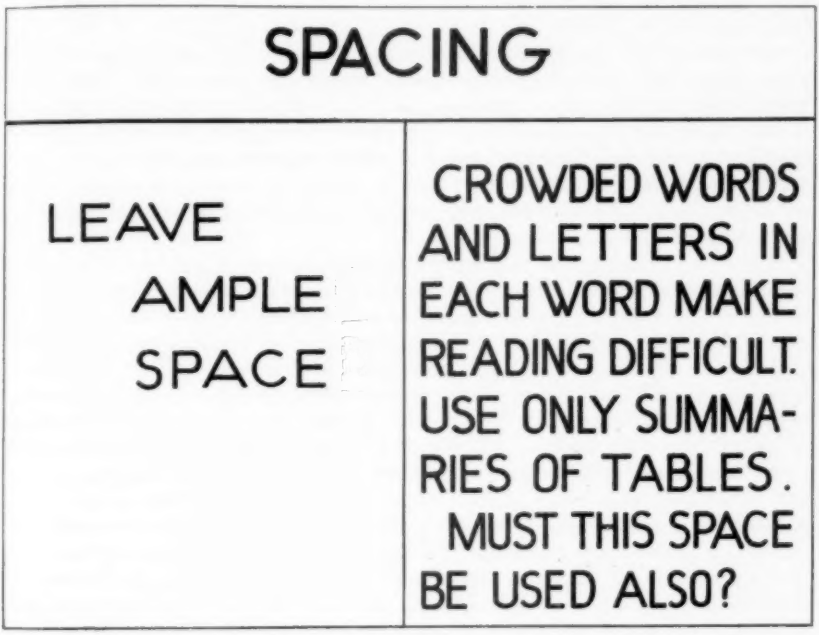

Fig. 2.—Proper spacing and the undesirable effect produced by crowding the letters and words.

STYLE OF LETTERING.—Authors of books on lettering state that by lettering one can express ideas such as femininity, antiquity, novelty, command, etc. Each style of lettering has a place but the plain heavy block, or old Egyptian type of hand lettering, in black, is to be preferred in making lantern slides. It is easy to read and will carry farther than any other style of lettering. Gummed black letters may be substituted for hand lettering. Typewriting, script, italics and fancy types should be avoided because they are difficult to read and do not carry well. There are many substitutes which may suffice for small group meetings, but do not use them beyond their limitations. Figure 1 illustrates the style of lettering to be preferred and some of the styles to avoid.

SIZE OF LETTERING.—Extensive tests by competent people have shown that the average person can read 1-inch letters at about 30 feet, $1\frac{1}{2}$-inch letters at about 65 feet, 2-inch letters at about 100 feet, and $2\frac{1}{2}$-inch letters at about 130 feet. When a lantern slide is projected to a

5 by 6 image on the screen, it has been enlarged 24 diameters. It should be borne in mind that even though typewritten letters, natural size on the slide, have been sufficiently enlarged to be read at great distances, the original density is not present and they will fade out.

SPACING.—Should slides typify a 10-cent store window or should they have the distinction of the more exclusive department stores? Most certainly the user of a slide who crowds his data defeats his own purpose. It is the object which stands out that leaves the lasting impression. Figure 2 illustrates the proper spacing and the undesirable effect produced by crowding the letters and words.

HEADINGS AND SUBHEADINGS.—These should be brief, preferably not more than four words, and they should embody only the general thought. Too often headings are so long and so involved that by the time the public has deciphered them the speaker must pass on to the next slide, in which case the essential data are lost. When continuing slides are necessary, repeat the headings. It is better, however, to boil down the data so as to eliminate the necessity for successive slides giving long drawn-out tables.

GRAPHS.—Through a long educational process the public is becoming acquainted with trend lines, but again there is a limit to the number of these which one can comprehend in a few minutes. This is especially true if the lines intersect at several places. More than three trend lines per slide are apt to be confusing and should not be used.

Either the column, the bar, or the pie can be used to supplant tables, and if properly selected will help the public to visualize the comparison of one thing with another. These are used to clarify the information, and they should not be made complicated by working in too many factors. It is better to cover three factors well than to attempt to present a greater number of factors through different forms of cross hatching or shadings. A sketch of the object being discussed helps others to visualize the point; sketches of trees, animals, or other hosts of insects with proper notations helps to show infestations at different locations on the host. If objects are used to show comparative abundance, only one dimension should be used. People can't conceive increased volume. It is better to show increased quantities rather than volume.

TABLES.—In a flock of sheep the few scattered black ones will catch the eye of the passerby or casual observer much more quickly than the much greater number of white ones. So it is with tabular material—a great mass of figures becomes so confusing that each set of numbers is just another sheep, but totals or averages would stand out and leave an impression such as did the black sheep. The person who illustrates his talk with slides containing large amounts of tabular data invariably hunts over the figures on the screen and finally points out a few representatives sets of figures. Since this is the case, why should the slide contain more figures than those pointed out for representatives, or still better, the averages or totals of the detailed data?

It is a common fallacy to include on a slide data which are foreign to the subject just because they are available. For instance, if in presenting information on codling moth control, four columns of summary data would represent a 100 per cent effective chart. To add a column of equal

size on aphids just because the data were available would at once reduce the effectiveness of the codling moth data on the chart to 80 per cent.

Thirty letters and spaces across the slide and not more than 10 lines vertically leave ample space for emphasis and the letters can be large and heavy enough to be read at great distances.

Slides in succession have been presented on which the position of columns or tables has been shifted. If one starts with data concerning the check plots on the left, experiment No. 1 in the second position and experiment No. 2 in the third position, this same order should be retained in succeeding slides.

PHOTOGRAPHS.—In using photographs select those which show very clearly the point to be emphasized. If necessary, trim or mat out unrelated subjects such as telephone poles, people, rocks, etc. In taking pictures to be used in making lantern slides, strive for a contrasting background. It takes a certain amount of high lights and shadows to make pictures, but be careful of the extremes. Have a side light on the object being photographed. Don't have the light from behind the camera. It is much better to have a close-up of a few representative sample types of injury than to have several plants showing a variation, in which case no one type stands out. In most cases the public is well enough informed to know there is a variation from the one shown. Be careful to exclude stakes, poles, equipment and people, except when they have a direct bearing on the subject. When people and equipment are necessary, make sure the person is showing some action by operating the equipment rather than posing for his portrait.

Graphs, tables and photographs could be used here to illustrate the foregoing paragraphs. It is not deemed necessary, however, to use space in this way, in view of the fact that in this and other copies of the JOURNAL OF ECONOMIC ENTOMOLOGY will be found graphs, tables and photographs to illustrate the points in question.

USING SLIDES.—Material for slides should be carefully checked before being made into a slide to avoid the necessity for explanation at the time of presentation. Each slide should be marked with a tab to assist the lantern operator in case the slides get mixed. This tab should be placed on the lower left corner of the side facing the maker or operator so that upon one's looking through the slide the written material is in position for reading. The speaker should outline in a general way what the slide is to show before taking up the details. A long pointer or light indicator should always be available so that the speaker can stand to the side of the screen and place the pointer on each feature referred to. The speaker should face the audience at all times while talking, even though a pause may be necessary to point out the features referred to.

One alternative for reducing the amount of material on each slide is to use more slides, but it should be remembered that too many slides become tedious to the audience and are apt to lose their effectiveness.

These remarks have been directed rather specifically towards the use of slides at meetings such as the annual meeting of the Association, but the information applies equally well wherever they are to be used.

Film strips.—Film strips afford a desirable means for presenting subject matter to the layman or to students in the classroom. As the name

indicates, they are strips of standard (35 mm.) motion picture film containing material such as would be used in a lantern slide series. A special projector is necessary to show film strips. The Department of Agriculture has prepared about 40 film strips on various phases of entomology. The author will be very glad to furnish more information on these.

At a recent meeting the author was asked by a fellow entomologist if he had noticed how much better the papers from a certain state were presented, to which the reply was "Yes." Investigation showed that the people from this state had rehearsed before their group prior to coming to the meeting. This might offer a suggestion which would no doubt prove helpful to many others. Persons in one-man stations could practice on their wives and families.

The author has often heard the remark: "I hate to travel half way across the country to hear a long-winded discussion." So, it would appear that a paper that is worthy of presentation at these meetings is deserving of time and thought in the preparation.—1-29-37.

EASTERN BRANCH

PAPER-READING SESSION, EIGHTH ANNUAL MEETING
New York, N. Y., November 1936

Particle Size of Commercial Calcium Arsenates by Sedimentation Analysis

LYLE D. GOODHUE, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

To obtain more information on the puzzling problems connected with the manufacture and use of calcium arsenate, the Division of Insecticide Investigations has recently undertaken the study of the physical and chemical properties of all available commercial calcium arsenates. This paper is concerned principally with the determination of the particle-size distribution of the different samples as received from the manufacturers, and the correlation of this property with other values, such as density, loose bulking value, and angle of slope, which are often used to characterize a dust.

The efficiency of an insecticidal material is closely connected with its physical properties, especially the state of subdivision. The coverage obtained from a definite amount of material, the injury to foliage, and even the chemical composition itself are apparently influenced considerably by the particle size. The measurements reported here were made with the hope that some correlation could be made with the chemical and entomological data on these samples gathered from laboratory and field investigations.

Determination of particle-size distribution.—The mechanical analysis was carried out by means of sedimentation in the apparatus described by Goodhue & Smith (1936). The procedure was practically the same

except for minor modifications to adapt it to this particular material. The sedimentation medium was 95 per cent alcohol diluted with an equal volume of water at about 25° C. This medium is about three times as viscous as either alcohol or water. The greater accuracy in the coarse fractions seems to justify its use, although several hours are required to complete an analysis. Since there is probably no reaction between calcium arsenate and alcohol, the use of this mixture of liquids should intro-

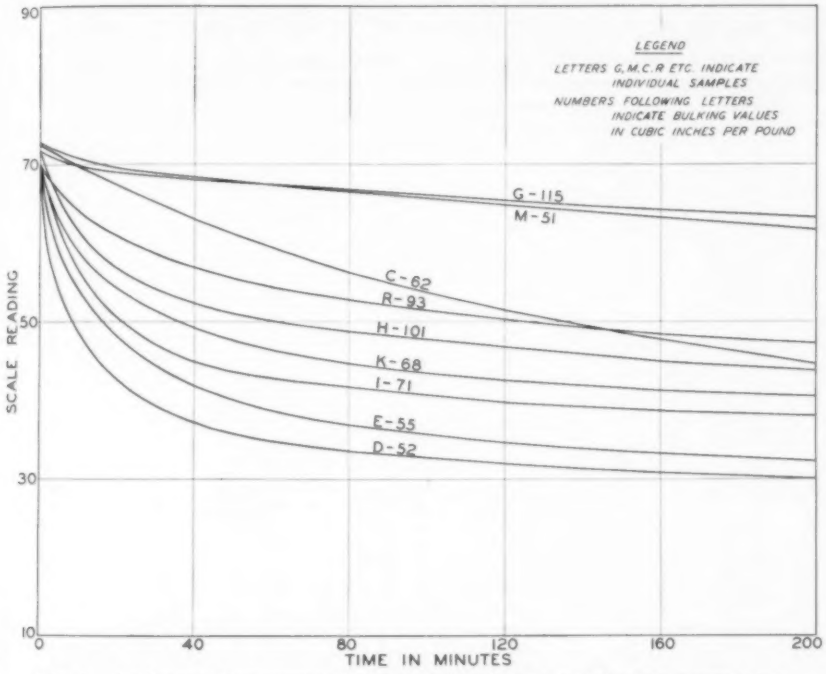

Fig. 1.—Sedimentation curves of nine samples of commercial calcium arsenates.

duce less error than if water alone were used. For precedent in the use of mixed solvents, reference is made to Odén (1921), who used mixtures of glycerin and water with results identical to those obtained in water alone. The solubility of the sample is also less in dilute alcohol than in water. Decahydronaphthalene dyed red to facilitate reading the interface was used as the upper liquid. The density was adjusted to .9000 ± .0002 gram per cubic centimeter at 25° C by the addition of a small amount of 1,2,4-trichlorobenzene.

The samples of calcium arsenate were analyzed as received. To avoid changing its composition and physical nature, no attempt was made to dry the sample. A 7.1 gram sample was used, .1 gram having been found to be the amount removed on the stirring brush. Dispersion was accomplished by mixing to a thick paste with a 2 per cent solution of sodium citrate in the dilute alcohol. A total of 10 cc. was added and the paste further thinned with dilute alcohol. Shaking for one hour on a mechanical

shaker appeared to give complete dispersion. Longer shaking up to 15 hours did not influence the results. The final concentration of sodium citrate, .03 per cent, after dilution in the sedimentation apparatus was sufficient in all but two cases, in which slight flocculation occurred. These two samples were run successfully in .06 per cent sodium citrate soluton. A 5 cc. portion of a 4 per cent solution of ammonium caseinate in dilute alcohol was also added to each sample as a protective colloid just before dilution in the sedimentation apparatus. The viscosity and the density of the medium containing the stabilizers were used in the

Table 1.—Particle-size distribution in 22 commercial calcium arsenates.

Sample	Percentage by Weight between the Indicated Radii					
	Above 20μ	20–10μ	10–7.5μ	7.5–5μ	5–3μ	Below 3μ
A	6	17	10	15	16	36
B	18	26	11	10	9	26
C	1	2	3	4	28	62
D	20	24	12	10	10	24
E	11	20	14	16	10	29
F	14	18	4	5	8	51
G	3	2	0	2	2	91
H	6	17	7	8	9	53
I	8	25	9	13	7	38
J	5	18	11	8	5	53
K	6	17	9	11	12	45
L	8	18	8	9	7	50
M	1	5	0	2	5	87
N	5	15	7	11	7	55
O	6	11	5	11	13	54
P	10	20	10	12	8	40
Q	6	18	11	16	2	47
R	2	10	8	9	11	60
S	9	17	8	8	13	45
T	1	4	4	8	19	64
U	16	10	6	10	2	56
V	4	8	3	6	15	64

calculation of particle size. These two values vary slightly with different lots of 95 per cent alcohol.

All analyses were made in a water bath controlled at 25° C ± .05°. Twenty minutes was allowed for the suspension and the top liquid to come to this temperature, and 100 rapid strokes of the stirring brush were used to insure complete mixing of the suspension. Readings were taken every two minutes during the first 20 minutes, every four minutes up to 40 minutes, and after that at convenient intervals up to 350 minutes. The sedimentation curves were plotted and the particle-size distribution was obtained by Odén's (1916) graphical method.

The curves for nine of the samples are shown in fig. 1; the curves for the other 13 fall too near some of these to be shown in the figure. Table 1 contains the particle-size distribution for all 22 samples.

Density.—The density of each sample was determined in 95 per cent alcohol. About 4 grams was placed in a 25 cc. pycnometer, covered with alcohol and shaken. Before the sample settled, it was placed in a vacuum desiccator and allowed to stand 30 minutes under reduced pressure. Checks to .01 unit were easily obtained by this method. These values

are given in table 2. Although there is not a great variation in density, there seems to be a definite correlation between density and particle size. The finer the material the higher is the density. This will be discussed fully later in the paper.

Loose bulking value.—The loose bulking value at constant volume was obtained by sifting the sample through a 20-mesh sieve into a can 2 inches in diameter and $2\frac{3}{4}$ inches high, smoothing with a spatula to remove the excess and weighing to about .05 ounce. It was expressed in

Table 2.—Some physical constants of commercial calcium arsenates.

Sample	Density at 25°C*	Loose Bulking Value†		Angle of Slope
		Constant Volume	Constant Weight	
	grams per cc.	*cu. in. per lb.*	*cu. in. per lb.*	*degrees*
A	3.01	68	68	51.4
B	2.98	46	42	48.8
C	3.28	62	69	55.5
D	2.98	52	60	52.2
E	2.95	55	57	50.8
F	2.99	70	66	50.4
G	3.14	115	111	46.1
H	3.14	101	93	50.4
I	3.00	71	64	50.9
J	3.07	69	78	48.4
K	3.14	68	69	51.4
L	3.05	70	74	49.4
M	3.32	51	48	51.8
N	3.10	73	69	48.8
O	3.15	72	72	50.9
P	3.02	63	72	50.1
Q	3.04	83	81	50.4
R	3.12	93	84	49.8
S	3.11	78	78	49.8
T	3.13	73		56.7
U	3.13	79		51.2
V	3.17	75		54.7

* Determined by S. Love, of the Division of Insecticide Investigations.
† Determined by R. C. Gaines, of the Division of Cotton Insect Investigations.

cubic inches per pound. The maximum variation in two check determinations was 4 cubic inches per pound, but usually the variation was much less. These values are reported in table 2. It will be noted that only two samples fall between 80 and 100 cubic inches per pound, which has been specified as the limit of variation in some states.

These bulking values, as will be pointed out later, showed so little correlation with particle size that the validity of the method was questioned. However, the bulking values at constant weight, determined by the Division of Cotton Insect Investigations with their special apparatus (Howard, 1922), agree in general with those determined by this method. Samples that bulk high by one method bulk high by the other and samples that bulk low give practically the same value by both methods. Such a determination depends so much on the size and shape of the container that results cannot be expected to agree more closely.

Angle of slope.—The property of flowing freely and dusting well has been expressed quantitatively by Wilcoxon & McCallan (1931) in con-

nection with their study of dusting sulfur. They allowed the dust to form a cone by flowing slowly through a funnel above the center of a circular disk until there was no further increase in the altitude of the cone. They then measured the altitude and calculated the tangent of the angle of slope by dividing the altitude by the radius of the disk. Dusts that flow freely and dust well give a low angle of slope. The values ap-

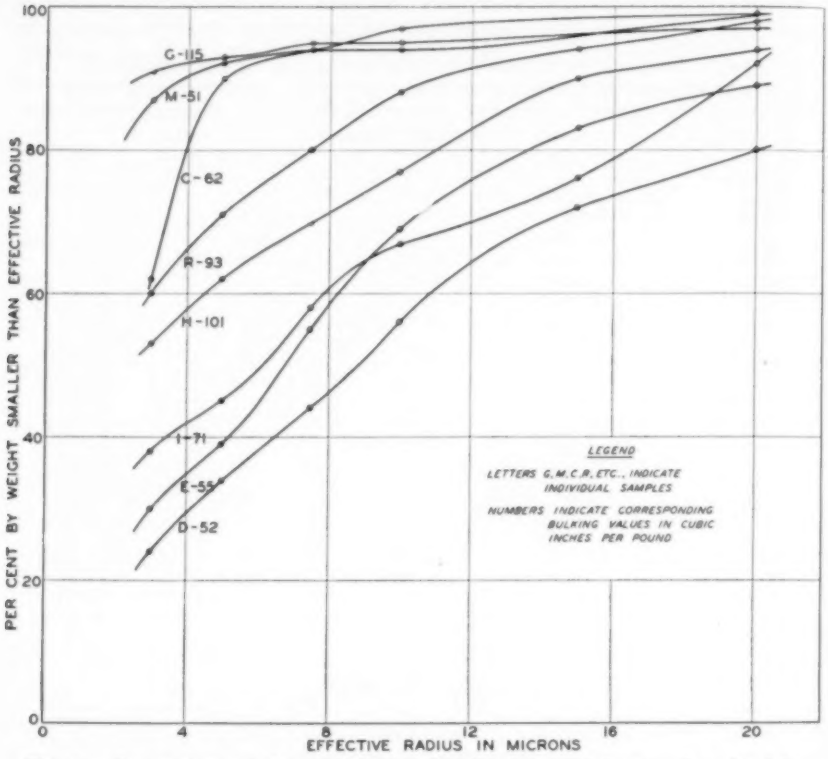

Fig. 2.—Comparison of the particle-size distribution of eight samples of calcium arsenate by the use of cumulative frequency curves.

pearing in table 2 were obtained in this manner by using a 3-inch disk and a funnel with an opening of one-fourth inch supported $3\frac{1}{2}$ inches above the disk. The variation between different samples of calcium arsenate was not great. Between the values for calcium arsenate, however, and the angle of slope for Paris green, 30 degrees, there is a great difference.

Discussion of results.—Results of a sedimentation analysis may be expressed graphically in several ways. The sedimentation curve itself gives considerable information, fig. 1. Borchers & May (1935) recommend the use of this curve with the manometer readings divided into 100 units in connection with a table showing the distribution in the different fractions. In fig. 1 the curve for the finest material is highest on the graph. Although the sedimentation curves do not give a complete

picture, they do give a good comparison of different samples of the same material that are run under identical conditions.

Odén (1916, 1921, 1926) prefers to represent the different fractions as an area under the ordinary bell-shaped frequency curve. However, to

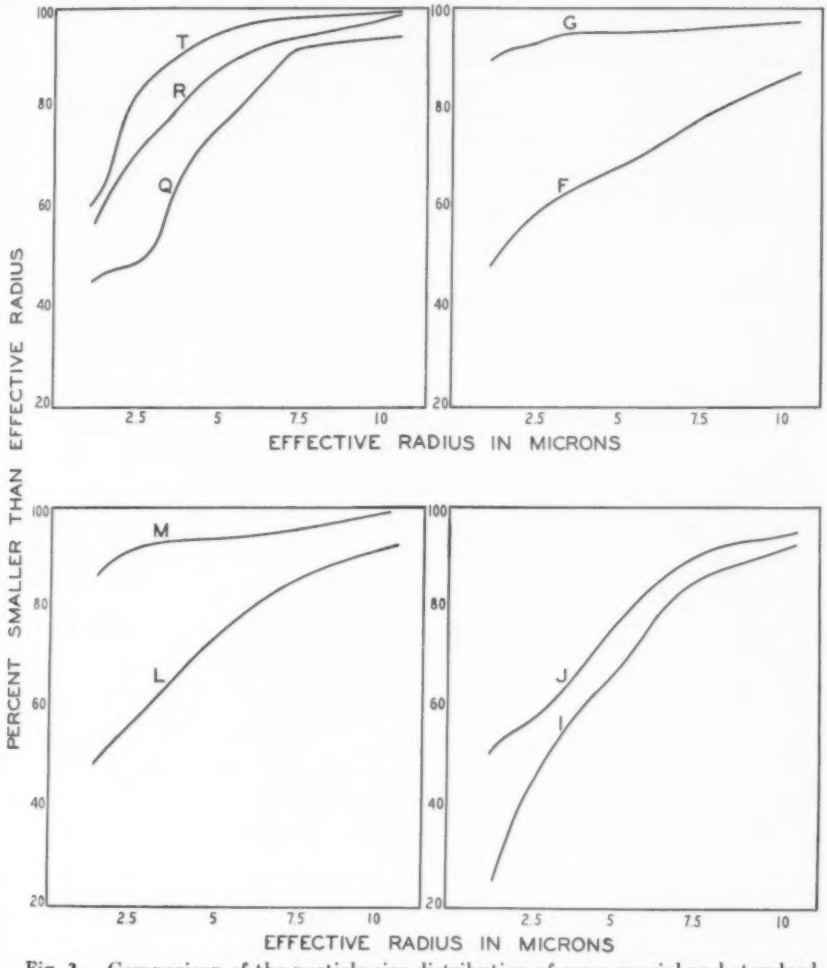

Fig. 3.—Comparison of the particle-size distribution of some special and standard samples put out by four companies. Each quadrangle contains results from samples furnished by one company. Samples T, R, G, M, and J are special grades, while Q, F, L and I are standard grades.

avoid integration to determine the amount in any fraction, the results can be plotted as in fig. 2, which gives a curve typical of a portion of a cumulative frequency curve. From this type of curve the relative fineness of a material can be noted at a glance. The highest curve represents the finest material.

The different samples vary considerably in particle size. As shown in table 1, the finest dust has 91 per cent below a radius of 3 microns while the coarsest has only 24 per cent in this range. Three samples have only 1 per cent above a radius of 20 microns while two of the coarse dusts have 18 and 20 per cent in this fraction.

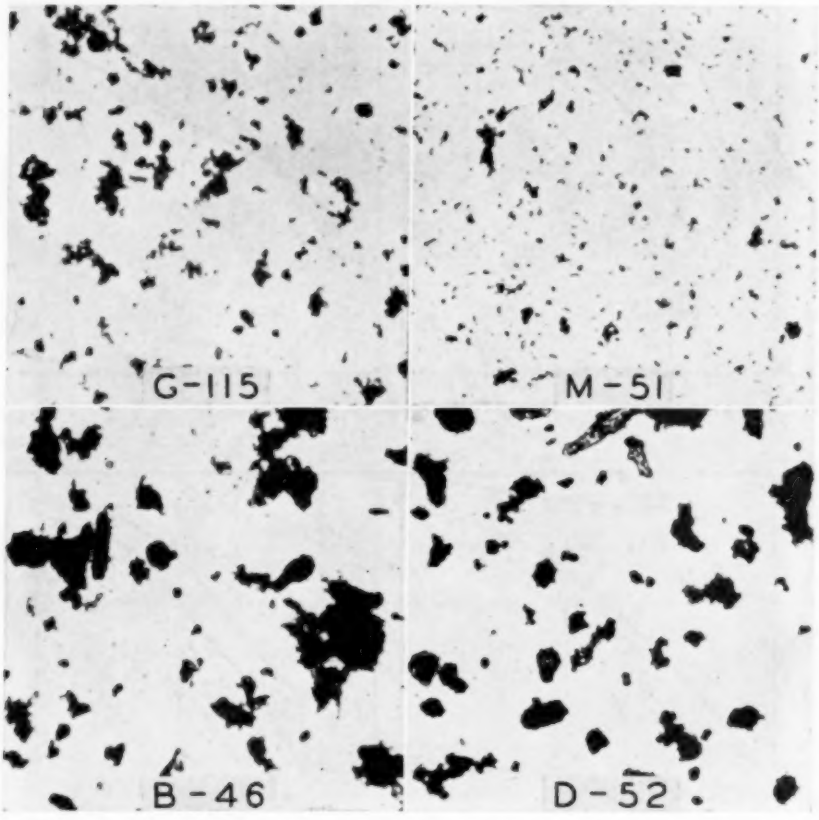

Fig. 4.—Photomicrographs of two of the finest and two of the coarsest samples under the same magnification (×154). The letters indicate the samples and the numbers indicate the bulking values in cubic inches per pound. These photomicrographs were prepared by E. L. Gooden.

Of the samples analyzed, G, J, M, R and T were special grades produced regularly by companies also producing another grade of calcium arsenate. In fig. 3 the particle-size distribution in the special grades is graphically compared with that in the standard grades represented by samples F, I, L and Q. In every case the special is finer than the standard grade. One company furnished two special grades, both of which were finer than their standard grade.

The special grades are not only finer than the standard grades, but they have, in every case, a higher density. With a few scattered excep-

tions this generalization that the finer materials have the higher density can be extended to the entire lot of samples. When the samples are divided into three groups, coarse, medium and fine according to particle size, and low, medium and high according to density, it is found that samples A, B, D, E, I, K, P and Q fall in the coarse group and samples A, B, D, E, F, I, P and Q fall in the group having the lowest density. Except for samples K and F the correlation in th s group is excellent. Five out of the seven samples of fine particle size also fall in the group with high density. In the medium groups there is some overlapping, but in general the correlation is very good. The reason for this correlation between density and particle size is not at present apparent. Further work is needed to explain it and certain other correlations that are mentioned in an article by O. A. Nelson and C. C. Cassil (page 474, this issue).

It is surprising to note, in figs. 1 and 2, that samples G and M show the highest and lowest loose bulking values, respectively, and yet they are both very fine materials. Sample C is a relatively fine dust, but its loose bulking value is very low. Sample D, the coarsest sample of the lot, is within one unit of the bulking value of M, which is next to the finest sample. The order of the samples when arranged according to their loose bulking values is quite different from the order according to their fineness (arbitrarily judged by the amount smaller than 5 microns in radius).

In general, a coarse material will give a lower loose bulking value than a more finely divided one. The majority of the values reported here give an indication of the fineness of the material, but since misleading results are sometimes obtained, the use of this property as a means of estimating the particle size can hardly be recommended.

The photomicrographs in fig. 4 do not show any great difference in particle size or form between the two finest samples, G and M. M and D, having low loose bulking values, are obviously extremely different in particle size. The photographs also give a check on the sedimentation method. The two coarsest samples by sedimentation analysis, B and D, appear very coarse in the picture while the two finest samples, G and M, also indicate the sedimentation value to be in the right magnitude. Although it is difficult to choose an average field, other observations and photographs did not reveal any samples of particle size noticeably different from that determined by sedimentation.

A study of the data in this paper and those obtained by chemical analysis indicates that there is a correlation between chemical composition and particle size as well as between density and particle size. Also the amount of soluble arsenic varies with particle size. Contrary to expectations, the finest materials were found to have the least soluble arsenic. These correlations will be discussed by O. A. Nelson of the Division of Insecticide Investigations, in a paper dealing with chemical composition.[1] Field tests on some of these samples have also been conducted by the Division of Fruit Insect Investigations and will be reported by them later.

[1] See p. 474.

Summary.—The particle-size distribution, the loose bulking value, the density and the angle of slope were determined for 22 commercial calcium arsenate samples. The particle-size distribution and loose bulking value varied greatly, while the density and angle of slope showed less variation.

The special grades produced by some of the companies were, in every case, finer than their standard grades.

A comparison of the loose bulking values and the particle size by sedimentation showed little correlation. It is pointed out and substantiated by photographs that the bulking value so often used as a measure of particle size is unreliable and often entirely misleading.

A correlation between density and particle size has been pointed out. The finest samples have the highest densities.—3-13-37.

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An Examination of Commercial Calcium Arsenates

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Most of the commercial arsenates are prepared by simply adding the proper quantity of a dilute solution of arsenic acid to a suspension of hydrated lime at some fixed temperature, usually near the boiling point. Just what compounds are formed depends upon the conditions of the process, and complete information concerning those compounds is difficult to obtain.

Table 1 gives the results of an examination, by the only available methods, of several brands of insecticidal calcium arsenate on the United States market in 1936, and for comparison there are also given what figures are available concerning the same brands as sold in previous years. The 1930 analyses were reported by Smith & Murray (1931), those for 1933, 1934 and 1935 by Pearce, Norton & Chapman (1935).

Commercial calcium arsenates are products containing between 40 and 47 per cent of arsenic pentoxide, which is combined in some manner with 30 to 42 per cent of calcium oxide, small proportions of calcium hydroxide

Table 1.—Analyses of various brands of commercial calcium arsenate.

Brand No.	Year of Manufacture	Total CaO	Total As_2O_5	Total $CaCO_3$	Free $Ca(OH)_2$	CaO Combined with As_2O_5	Water-soluble Arsenic		Molar Ratio CaO/As_2O_5
							A.O.A.C.*	P.N.C.†	
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	
1	1930	46.07	42.58	2.	12.6	35.4	.06		3.41
	1936(A)‡	45.48	42.87	2.5	13.3	34.	.11	6.4	3.25
2	1930	42.26	41.63	12.8	1.5	34.9	2.37		3.25
	1933	45.08	39.47	4.2	13.9	32.2	.46	8.3	3.35
	1934	42.9	41.1	9.1	7.8	31.9	.12	7.2	3.18
	1935(B)	42.19	43.57	5.7	8.	33.	.18	11.5	3.11
3	1930	44.98	42.5	8.	3.6	37.8	.11		3.64
	1933	45.3	42.54	4.6	7.3	37.2	.04	.5	3.59
	1934	43.98	44.53	5.6	2.8	38.7	.02	.5	3.56
	1936(C)	44.55	45.34	5.2	4.1	39.6	.04	.5	3.49
4	1930	44.4	41.55	1.2	12.7	34.1	.2		3.37
	1936(D)	44.55	41.21	5.8	12.7	31.7	.11	7.6	3.15
5	1936(E)	43.77	40.19	6.4	13.4	30.1	.08	8.7	3.07
6	1930	40.43	43.7	2.4	7.4	33.7	.31		3.16
	1933	46.82	40.18	4.6	12.	34.9	.01	1.2	3.56
	1934	43.48	41.8	18.8	.1	32.9	.38	1.	3.23
	1936(F)	45.37	40.98	2.1	14.1	33.5	.08	6.3	3.35
	1936(G)	46.62	40.71	6.4	7.4	36.5	.08	.2	3.77
7	1936(H)	42.47	41.52	7.3	5.	34.6	.3	3.2	3.47
8	1930	43.3	41.52	2.6	5.8	37.4	.11		3.7
	1936(I)	44.72	41.99	1.8	14.8	32.8	.09	7.9	3.2
	1936(J)	44.69	43.26	2.6	9.1	36.4	.11	3.2	3.45
9	1930	47.7	40.32	1.4	8.4	40.6	.23		4.13
	1933	47.68	40.18	4.1	17.7	32.	.01	2.1	3.27
	1934	45.1	43.12	2.5	9.1	36.9	0.	2.1	3.51
	1936(K)	44.23	46.38	8.6	4.3	36.2	.15	3.5	3.2
10	1930	43.92	40.72	11.7	6.1	32.7	.11		3.3
	1933	43.76	40.04	2.6	12.1	33.1	.01	.9	3.3
	1934	47.04	42.25	9.3	7.5	36.2	.02	.2	3.52
	1936(L)	45.4	41.	2.2	13.6	33.9	.11	6.	3.39
	1936(M)	47.31	43.14	4.2	10.5	37.	.11	.6	3.53
11	1930	41.83	42.66	10.9	5.6	31.5	1.		3.03
	1936(N)	44.15	42.02	5.3	3.5	38.6	.05	1.9	3.76
12	1930	47.06	41.76	3.	11.9	36.4	.06		3.57
	1936(O)	44.49	40.77	15.	2.8	33.9	.15	1.	3.41
13	1930	44.58	42.29	8.	6.1	35.5	.11		3.44
	1933	45.85	43.45	1.9	8.9	38.	.01	1.6	3.59
	1936(P)	45.23	42.19	2.9	11.9	34.6	.08	6.1	3.37
14	1930	40.96	43.02	7.1	5.7	32.8	.2		3.12
	1933	43.	42.5	4.	5.8	36.4	.03	6.6	3.51
	1934	43.8	42.12	4.8	8.6	34.6	.29	5.7	3.37
	1936(Q)	43.9	42.31	2.7	8.9	35.7	.08	6.8	3.46
	1936(R)	45.15	42.8	3.7	7.2	42.2	.08	.7	3.66
	1936(T)	45.51	41.84	6.5	5.5	37.7		.2	3.7
15	1936(S)	44.55	45.31	3.6	7.1	37.9	.08	4.2	3.43
16	1930	47.28	41.13	5.5	9.6	36.9	.11		3.68
17	1930	42.87	44.35	6.1	2.8	37.3	.2		3.51
18	1936(U)	46.75	43.29	5.6	7.4	38.2		.6	3.6
19	1936(V)	46.15	43.55	6.	6.6	38.2		0.2	3.54

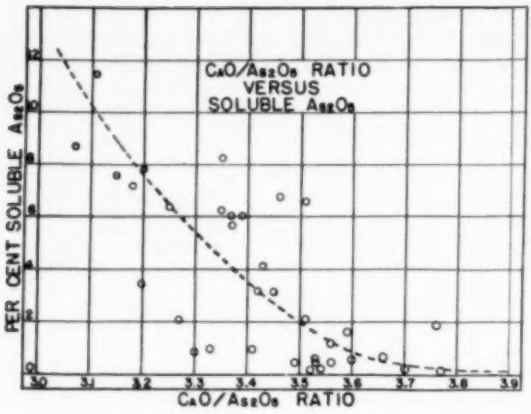
* Association of Official Agricultural Chemists (1935).

† Pearce, Norton & Chapman (1935).

‡ These lettered samples are the ones examined by L. D. Goodhue (1937) and reported by him under the same letters. Samples G, J, M, R and T were "specials," representing attempts made by the manufacturers to produce materials that would be less toxic to foliage and more toxic to insects.

and calcium carbonate, and traces of the oxides of iron and aluminum. Of these constituents the calcium hydroxide and the calcium oxide–arsenic pentoxide compounds are important, while the calcium carbonate and the oxides of iron and aluminum, etc., are impurities only and without insecticidal value.

Examination of the results in table 1 reveals that there is no relation



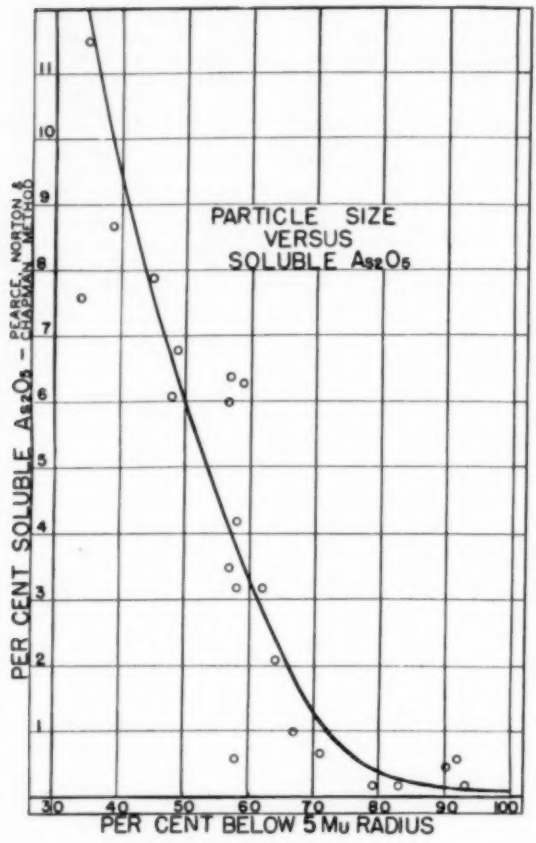


Fig. 1.—Above. **Fig. 2.**—Below.

between the percentage of free lime and the percentage of water-soluble arsenic whether determined by the method of the Association of Official Agricultural Chemists or the method of Pearce, Norton & Chapman (1935), or between the percentages of water-soluble arsenic obtained by the two methods (compare nos. 2, 3, 6, 9, 10, 14). Furthermore, there is considerable variation in the analyses and in the molar ratios of CaO/As_2O_5 in the same brands from year to year, as well as from one brand to another. This variation could be due to failure to reach equilibrium conditions in the reacting mixture, or to changes in the methods of manufacture from year to year.

The molar ratio CaO/As_2O_5 was calculated after the equivalent percentages of CaO in the $CaCO_3$ and the free $Ca(OH)_2$ had been deducted from the total percentage of CaO, so that the errors of all those analyses lessen the certainty of the ratio values. Because of the possibility of the coexistence of more than two compounds, these CaO/As_2O_5 ratios represent merely the average molar ratio of CaO combined with As_2O_5 and do not alone indi-

cate just what calcium arsenates are present. In the following paragraphs the anomalies discovered in the analysis of these calcium arsenates will be considered.

Calcium arsenates with five definite CaO/As_2O_5 ratios are known, forming a series from the soluble, acidic monocalcium arsenate, $CaH_4(AsO_4)_2$, to the very insoluble, basic tetracalcium salt, $Ca \cdot CaOH \cdot AsO_4$. In addition, the senior author has obtained conclusive evidence for the existence of solid solutions in the region between tricalcium and tetracalcium arsenate wherein the tricalcium salt is capable of dissolving large quantities of tetracalcium arsenate. In the manufacture of commercial calcium arsenate the formation of the acidic monocalcium salt is impossible because of its high solubility, and the presence of the basic tetracalcium salt in the final product is unlikely because, although readily formed at low temperatures (20–25° C), this salt appears to be unstable at elevated temperatures (62° C and above) such as are used in practice. This leaves the calcium arsenates varying in acidity from the dicalcium salt to the solid solution of tri and tetra salts as the only ones likely to be found in commercial preparations.

The phase-rule investigations into the formation of the arsenates of calcium as carried out by Smith (1920), Pearce & Norton (1936), and the senior author (unpublished) offer a ready explanation for the variability of the commercial products for they show that the different arsenates can be prepared simply by altering the conditions of the process, and that there is great difficulty in attaining equilibrium.

No direct analytical method has yet been devised for determining accurately the relative quantities of the various calcium arsenates in a mixture of these salts. It might be thought that the differences in solubility would offer a point of attack. However, when the commercial product is treated with water the excess lime dissolves so rapidly that it continually precipitates whatever arsenic might be given up by such a salt as dicalcium arsenate. Thus, the results of the A.O.A.C. method for soluble arsenic usually shed no light on the question. There is merely a shift in the relative quantities of the various compounds present, tending toward the establishment of true equilibrium.

The method of determining soluble arsenic proposed by Pearce, Norton & Chapman (1935) offers more possibilities. The removal of the relatively soluble free lime and the very low solubility of the more basic arsenates retard the readjustment of equilibrium so much that the more soluble calcium arsenates can reveal their presence.

Table 1 shows the values obtained by this method to vary between .2 and 11.5 per cent. The present authors' unpublished phase-rule data indicate that only the dicalcium arsenates $CaHAsO_4 \cdot \times H_2O$ are soluble enough to give the higher values found; so it seems practically certain that some products contain such a salt. However, because these arsenates do not dissolve as such, but undergo hydrolysis, the solubility figures cannot be converted to percentages of dicalcium arsenate present, and only a qualitative idea of the relative amounts in the various brands can be obtained. On the basis that 3.84 is the largest ratio ever found by the senior author for pure material in equilibrium at 62° C, the lowest ratio found in 1936, namely, 3.07 per cent in sample 5, E, might con-

ceivably indicate the presence of 43 per cent of dicalcium arsenate, $CaHAsO_4 \cdot H_2O$. This is a maximum estimate. It is highly probable that the basic solid solution present under such conditions is not so basic as assumed. It is also more than likely that tricalcium arsenate is present in considerable quantities in commercial calcium arsenates, thus adding still more to the difficulty of estimating the percentage of dicalcium arsenate present in the product.

Despite the lack of equilibrium conditions in the manufacture of calcium arsenate, there is a lessening of solubility with increasing ratio of CaO/As_2O_5, as indicated by the phase-rule studies. This is shown in fig. 1. It is interesting to note from fig. 2 that there is also an apparent correlation between soluble arsenic as determined by the method of Pearce, Norton & Chapman, and particle size as determined by Goodhue (1937). This is perhaps due to the fact that dicalcium arsenate crystallizes readily, and hence samples containing considerable quantities of this compound will tend to have more large particles. Finally, it may be pointed out that in every case the special grade of calcium arsenate is finer, more basic, and has less soluble arsenic than the regular product of the same manufacturer. This indicates that the methods used for special brands are such as to permit a nearer approach to equilibrium.—3-13-37.

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Tests of Cattle Fly Sprays by the "One-half Cow" Method

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Two purposes mark the tests described herein. First, there was an attempt to evaluate certain unexplored compounds against stable flies, and second, to obtain information relative to the effectiveness of some of the more common proprietary cattle fly sprays in repelling horse flies.

The different flies feeding on the test animals were recorded in two groups, "stable flies" and "horse flies." The true stable fly, *Stomoxys calcitrans* Linn., was by far the most abundant, with the house fly, *Musca domestica* Linn., and the horn fly, *Haematobia irritans* Linn., relatively

few in number. The principal species of horse flies were *Tabanus lineola* Fab., *T. nigrovittatus* Macq. and *T. daeckei* Hine, the latter appearing only in the earlier tests. *T. sulcifrons* Macq. and *T. atratus* Fab. were generally present and although conspicuous, because of their large size, never approached the smaller species in total numbers. Representatives of the genus *Chrysops* were seldom observed.

A strip of filter cloth, 4 by 8 feet, and held in position by two men, was used to cover the right side of the cow during spraying. Longitudinal cuts had been made which permitted a part of the cloth to protect the inside of the right legs and also lessened the possibility of the cow becoming entangled in the cloth in case of nervousness or kicking. Thirty cubic centimeters of spray were applied to the left side of the cow by means of a *DeVilbiss* atomizer of the type adopted by the National Association of Insecticide and Disinfectant Manufacturers as official for Peet-Grady tests. Air for the sprayer was obtained from a pressure tank which was pumped up to 30 pounds pressure before spraying. After spraying, the cows were tethered in the pasture by means of ropes 6 feet long attached to iron stakes. The spacing was such that they could not make physical contact with each other. Each cow wore a tagged halter and retained the same number throughout the experiment. Counts of the number of flies on each side were made at half-hour intervals.

Each cow was sprayed with the same material on three successive mornings. All cows were washed with soap and water on the evening of the third day and the sprays were rotated on the following morning. This procedure continued until each proprietary material had been applied to five different cows, the only exception being that in the fifth replication the materials were applied for four instead of three days.

There are few references in literature to the "one-half cow" method. Questions concerning the validity of this method arose during the course of the present experiment, but unfortunately time did not permit additional tests designed to supply the answers.

If the method is valid, it offers the following advantages over certain other types of field testing:

(1) A relatively large number of materials can be tested simultaneously, since only one cow is needed for each material. The flies on 15 to 20 cows can be counted by two men in one-half hour. Using certain other methods, only three to five materials could be tested on the same number of cows.

(2) In the case of unknown materials, less injury to the cow would probably occur if but half the animal were sprayed. This would be particularly true if burning of the skin or loss of hair resulted from the application.

(3) An unsprayed check is adjacent to each treated half. A comparison of the treated and untreated sides should measure, therefore, the effectiveness of the spray and thus the fly susceptibility of the cow would not be a complicating factor.

(4) Since the performance of materials can be calculated every half hour, the period over which a material is effective can be more accurately determined.

Statements 1 and 2, above, apparently require no further discussion.

Statement 3, however, in order to be valid, must be based on certain assumptions which, to our knowledge, have not been proved experimentally: (1) If a cow is untreated, an equal number of flies will feed on each side. (2) The repellence of a spray is confined to the treated area. (3) Density of insect population does not materially affect the results.

The first assumption has probably been taken for granted or else any

Table 1.—Summary of fly repellency tests.

Spray No.	Percentage of Flies on Treated Side						
	Replications*					Average Replications 1–5	Average Replications 1–4
	1	2	3	4	5		
				Horse Flies			
1	27	44	40	27	32	34	35
2	28	35	40	37	33	34	38
3	42	32	37	45	42	39	40
4	44	36	38	37	39	39	39
5	27	40	39	46	42	39	39
6	37	27	36	35	21	31	34
7	28	41	37	47	44	40	39
8	41	41	29	30	36	36	38
9	55	42	47	47		47	48
10	52	40	39	37		42	43
11	39	44	31	42		39	39
12	57	43				50	42
13			57			57	
14				38		38	
15					42	42	
16					44	44	
17					44	44	
18					39	39	
				Stable Flies			
1	34	50	43	33	35	39	40
2	34	53	47	41	34	42	44
3	30	37	48	42	40	39	39
4	45	48	45	49	53	48	47
5	41	50	44	40	51	45	44
6	29	27	50	38	33	35	36
7	30	46	47	40	43	41	41
8	31	43	46	45	45	42	41
9	45	46	51	43		46	46
10	36	52	51	52		48	48
11	50	46	49	48		48	48
12	40					41	
13			52			52	
14				45		45	
15					55	55	
16					46	46	
17					42	42	
18					47	47	

* Average of counts made on the days that the sprays were applied.

difference has been thought to be negligible. The second assumption requires more careful consideration. The odor of a material is not confined to the treated side and, if odor is an effective factor in repellence, not only is this assumption invalid but also the cows should be tethered a considerable distince apart in order that the effect of various materials will not overlap. Furthermore, a certain amount of spray material can be transferred from the treated to the untreated side by either the head or the tail. It is obvious, if repellence extends to the untreated side, that calculations based on the number of flies observed thereon are not correct measures of the performance of the materials under test. Also, it is evident that if present, the degree of repellence on the untreated side need not be proportional to the effectiveness of the material. In regard to the third assumption, most investigators agree that an insect popula-

tion of uniform density is desirable when directly comparing the effects of a number of materials. For this reason, it would seem advisable to select cows or groups of cows of approximately equal fly susceptibility. The validity of statement 4 relates directly to the validity of statement 3.

The sprays under consideration were tested under code numbers and, since all of them were either proprietary materials or unexplored compounds, the data will be presented under these numbers. The percentage of flies on the treated side was decided upon as the measure of performance of a material. This percentage is obtained by dividing the number of flies on the treated side by the total flies on the cow. It is interpreted as follows: Of the total flies on a cow a certain percentage were feeding on the treated side. Theoretically this figure should never exceed 50 per cent. Other calculations could have been made, such as by use of Abbott's formula, but it was felt that a clearer picture of performance would be given by dividing the number of flies on the treated side by the total flies on the cow, table 1. In addition, the percentage of the total population carried by each cow was determined by dividing the total number of flies on each cow by the total number of flies on all cows. Since variations due to both treatment and fly susceptibility of the cows were included, no correlation was noted between the percentage of the total population per cow and the percentage of flies on the treated side of a cow.

Averages of performance for replications one to four are tabulated for both stable flies and horse flies in separate columns of table 1. The percentages of stable flies on the treated halves were calculated each half hour in an effort to determine the rapidity with which the sprays lost their repellent effect. The variations were too large for even an indication of loss of repellence.

An analysis of variance following that of Huber & Sleesman (1935) was made in which the percentage of stable flies on the treated half was selected as the measure of performance. Data pertaining to materials 1 to 11, inclusive, and replications 1 to 4, inclusive, were analyzed with the following results: ratio of treatment to experimental error, 7.54; and ratio of replication to experimental error, 23.83. The effects of both treatment and replication were significant at odds greater than 99:1 as determined by Fisher's (1932) "Z" test. It should be noted that the varition due to replication was more than three times as great as the variation due to treatment. A difference of 6.5 per cent was found necessary for significance at odds of 19.1 and 9.85 per cent at odds of 99:1.

A further analysis of variance was made in which the percentage of horse flies on the treated half was selected as the measure of performance. The data pertaining to materials 1 to 11 inclusive, and replications 1 to 4 inclusive, were again used. The calculated variations were as follows: replication, sum of squares, 28; treatment, sum of squares, 657; and error, sum of squares, 1403. Mean squares were 9.3, 65.7 and 46.6 respectively. These figures indicate that the recorded data are meaningless. Applying Fisher's "Z" test for significance, the calculated Z was less than half the value computed for a probability of 19:1, which proved these data to be of no value.

Conclusions.—Data pertaining to the "one-half cow" method of test-

ing cattle fly sprays have been presented. If valid, certain advantages are offered by this method. However, the validity of this method is open to question. Significant difference in the percentage of stable flies on the treated side was obtained between certain sprays. Analysis of the data pertaining to horse flies indicates that these data are meaningless. —4-16-37.

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PACIFIC SLOPE BRANCH

PAPER-READING SESSION, TWENTY-FIRST ANNUAL MEETING

Seattle, Wash., June 1936

Effects of Subzero Temperatures on Populations of Western Pine Beetle[1]

Dendroctonus brevicomis Lec.

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Importance of temperature as a limiting factor in the distribution and seasonal abundance of insect species has long been recognized. Each species, through adaptation, has become adjusted to life within the range of temperatures prevalent in its natural habitat. Even so, temperatures may occasionally occur that are fatal to part of an insect population. Mortality of an insect pest, as the result of critical temperatures, may influence its seasonal abundance at times and hence be an important consideration in determining whether or not to adopt direct control measures. Recent subzero temperatures in the ponderosa pine region of the Pacific northwest have given an opportunity to determine the lower critical temperatures for one of our most destructive tree-killing bark beetles, the western pine beetle, *Dendroctonus brevicomis* Lec.

The western pine beetle is a transition zone species inhabiting the Pacific coast portion of the range of ponderosa pine from Baja, Calif.,

[1] This study has been made possible through the cooperation of several agencies and many individuals. We owe particular thanks to the personnel of the Emergency Conservation Work, without whose funds and services the study could not have been carried on. Members of the Forest Service and Indian Service were very helpful during the winter of 1932–33 in collecting bark samples from many areas, some of which were reached only under the most difficult conditions, and required back-packing of bark over many miles of deep snow. We have drawn heavily upon Bureau of Entomology and Plant Quarantine office reports by J. A. Beal and K. A. Salman, to whom credit for much of the original work is due. Other members of this Bureau who have aided at some time in the study are W. J. Buckhorn, J. M. Whiteside, P. C. Johnson, F. W. Bacon and E. W. Wohletz. J. M. Miller, who has given a great deal of study to temperature effects under laboratory conditions, has been very helpful with information and suggestions.

[2] Publication of this paper has been secured by payment of the printing charge.

to British Columbia, and eastward into Idaho and Montana. In this area it is normally subjected to air temperatures of −10 to 105° F. Since critical temperatures for this beetle lie below −5° F and above 105° F, it is apparent that the species, being protected to some extent by insulating layers of bark, is well adjusted to the usual temperatures in its geographic range.

In certain parts of its normal range, abnormally low temperatures, which are fatal to part of the overwintering broods, occur from time to time. On the western slopes of the Sierra Nevada and in the southern portion of its range subzero temperatures sufficiently low to cause western pine beetle mortality rarely occur, but on the eastern slopes of the Sierra Nevada and Cascade mountains and in the northern part of its range such temperatures are more frequent. In central Oregon, which is typical of the entire area covered in the present study, there is appreciable winter killing of western pine beetle broods about once in three years, and severe killing perhaps once in 10 years. These killing temperatures cause an immediate reduction of western pine beetle populations which, in certain instances, is reflected in a temporary decrease of damage to the host tree. Temperatures within its normal range do not fall sufficiently low to exterminate the beetle population, and infestations soon resume their normal course, which is primarily influenced by other factors. There is evidence that the northeastern limits of distribution of the western pine beetle are determined by minimum winter temperatures.

Following three recent periods of subzero temperatures in eastern Oregon and northeastern California, extensive field examinations and detailed observations have been made to determine (1) the immediate effects of low temperatures upon overwintering western pine beetle broods, as measured by the amount of mortality soon after the low temperatures occur; (2) the influence of various factors upon the amount of mortality; (3) the net effect of low temperatures in reducing overwintering broods, as measured by the amount of emergence in the spring following periods of cold weather; and (4) the effects of reduced beetle populations upon subsequent generations and the general trend of beetle outbreaks. The present paper summarizes the results of these observations and indicates to what extent this information may have practical value in connection with the conduct of control projects.

Habits of the western pine beetle.—The habits of the western pine beetle, particularly those of the overwintering brood stages, have an important bearing upon its resistance to low temperatures, so it is necessary briefly to review certain of these.

Female beetles lay eggs along galleries constructed in the phloem, or inner bark. The larvae, upon hatching, mine for a time in the phloem, then most of them migrate outward into the corky bark where, after further growth, transformation into the pupal and adult stages takes place. For a more complete discussion of the life history and habits of this insect, see Hopkins (1909).

Unpublished studies by Salman show that the first-instar larvae confine their activity to the inner bark. The second-instar larvae live both in the phloem and in the outer bark, but still near the phloem. The third and fourth-instar larvae, for the most part, mine in the outer bark.

For convenience in the present temperature study, the larvae have been divided into the following two groups: (1) small larvae, consisting of the first and second instars; and (2) large larvae, consisting of the third and fourth instars. These terms are somewhat misleading in that size is not always a true criterion of the larval instar. More exactly, the division is one of difference in habit, for the small larvae feed primarily in or very near the phloem, whereas most of the large larvae live in the outer bark.

Usually, if not always, a majority of the brood overwinter as large larvae, but an appreciable number of eggs and small larvae may be found. Young adults[3] and parent adults comprise a very small and relatively unimportant portion of the total overwintering brood.

In the winters of 1932–33 and 1935–36, large larvae were found to predominate, as usual. This was determined by data from sample plots and a large number of bark samples from infested trees. While the proportion of different brood stages varies considerably on different areas and in the

Table 1.—Overwintering brood stages of *Dendroctonus brevicomis*, winter of 1932–33, Modoc county, Calif.

Per Cent Eggs	Per Cent Small Larvae	Per Cent Large Larvae	Per Cent Young Adults
1.5	26.8	71.1	.6

different years, data taken from 393 samples from 2 per cent of the infested trees on a large control project in Modoc county, Calif., during the winter of 1932–33 show the general relationship, table 1.

In the light of general observations, it is believed that the percentage of large larvae shown in table 1 may be somewhat too low.

Normal mortality.—For the western pine beetle, as for any insect species, there is a more or less constant death rate during the developmental period. This may be termed the normal or usual mortality, and must be determined before the abnormal mortality can be recognized as such.

Population counts at different stages of western pine beetle development, which were made over a period of 11 years in the same general region to which our winter mortality records apply, have been summarized in an unpublished report by Keen. These counts show the following averages: 432 eggs are laid to each square foot of infested bark, 346 larvae hatch, 200 reach the full-grown larval stage, and only 63 adult progeny emerge from the bark. Thus the normal hazards of life for the western pine beetle, under all conditions from the egg to the adult stage, cause a reduction of about 85 per cent. That most of this mortality occurs during transformations and little during a given stadium was found by Beal in unpublished laboratory studies of brood development.

Even in mild winters there are several months in which no transformations take place. During the quiescent winter period, brood mortality is usually not in excess of 5 per cent when killing temperatures do not occur. This has been shown through the examination of several thousand

[3] Young adults are considered to be those newly formed individuals that have not emerged from the trees in which they developed, as contrasted with the parent adults which have emerged, attacked trees, and produced progeny.

square feet of bark containing overwintering broods of different stages and from many different areas.

Eggs and small larvae, which overwinter in the phloem or very close thereto, appear to experience such altered conditions of food and environmental moisture that, upon resumption of activity in the spring, very few are able to complete their development. Unpublished caging studies by Buckhorn have shown that, in mild winters, trees containing overwintering eggs and small larvae have produced only about 20 per cent as many progeny as those with overwintering large larvae. Thus the normal hazards for overwintering small larvae are much greater than for large larvae.

Table 2.—Mortality of *Dendroctonus brevicomis* brood in midwinter following the low temperatures of December 1932.

Areas in Oregon and Washington	Approximate Minimum Temp. ° F	No. Samples	No. Sq. Feet Infested Bark	Per Cent Brood Mortality
Klickitat county, Wash. (Goldendale area)	− 3	17	15.8	9.2
Deschutes National Forest, Ore. (Metolius area)	−12	21	20.2	57.9
Umatilla National Forest, Ore. (Heppner area)	−14	20	12.1	29.3
Klamath Indian Reservation, Ore. (Modoc Point)	−19	20	23.	74.1
Ochoco National Forest, Ore. (McKay creek)	−21	164	114.2	56.1
Deschutes National Forest, Ore. (Summit Stage station)	−30	54	39.4	84.5
Deschutes National Forest, Ore. (Panhandle project)	−33	40	17.4	82.7

Winter mortality caused by low temperature is easily recognized, for the dead larvae present a characteristic leaden appearance which can be duplicated by exposing healthy brood to low temperatures under controlled conditions. Accordingly, when excessively low temperatures have occurred in the field, it is possible to determine the presence or absence of winter killing by direct observation. This reduction of brood by freezing can be measured rather accurately by sampling the population soon after low temperatures occur.

Immediate effects of low temperature.—In the present study the immediate effects of cold weather upon overwintering western pine beetles was determined through population counts made shortly after the cold weather of December 1932, February 1933 and November 1935. Samples of infested bark were obtained in the ponderosa pine stands east of the Sierra Nevada and Cascade ranges, from northern California to northern Washington. Most of these were from central and southern Oregon and northeastern California. All population counts were made by carefully shaving the samples of infested bark and recording all living and dead individuals. The dead were easily recognized during the first month or two following the low temperatures, but after that length of time they became increasingly difficult to find because of the disin-

tegration of the larvae, especially the small larvae. Because of limited personnel, it was impossible to make all of the counts within the desired time, so whatever errors were made in the counts tend toward underestimation of the effect of the low temperatures.

Table 3.—Mortality of *Dendroctonus brevicomis* brood in midwinter following low temperatures of December 1932 and February 1933.

Areas in Oregon and Washington	Approximate Minimum Temp. ° F	No. Samples	No. Sq. Feet Infested Bark	Per Cent Brood Mortality
Rogue River National Forest (Keno area)	−10	47	31.5	33.6
Klickitat county, Wash.* (Goldendale area)	−13	16	13.	40.6
Wenatchee National Forest, Wash.* (Entiat creek)	−14	39	18.7	26.1
Deschutes National Forest (Metolius area)	−22	30	18.5	46.1
Deschutes National Forest (Metolius area)	−22	50	43.1	47.
Umatilla National Forest (Ditch creek)	−25	50	28.1	50.2
Klamath Indian Reservation (General)	−25	37	52.3	87.6
Ochoco National Forest (Maury Mt.)	−26	41	18.6	53.
Klamath Indian Reservation (Long Bell area)	−26	20	9.	68.
Klamath Indian Reservation (Lamm Lumber Co.)	−26	20	10.2	75.
Fremont National Forest (Quartz valley)	−26	13	7.3	76.6
Whitman National Forest (Unity area)	−35	25	8.5	61.3
Ochoco National Forest (Snow Mt.)	−35	101	40.9	79.9
Malheur National Forest (Burns area)	−35	46	22.6	87.3
Ochoco National Forest (Snow Mt.)	−35	45	20.8	90.7
Malheur National Forest (Bear valley)	−44	86	54.6	81.3
Malheur National Forest (Murderer's creek)	−44	53	22.5	84.6
Malheur National Forest (South Fork John Day)	−44	65	32.7	86.8

* Washington areas affected only by February 1933 freeze.

In all, 1864 samples comprising 1002 square feet of infested ponderosa pine bark, which contained 185,169 living or dead western pine beetles in different brood stages, were examined. It was found that 25–50 samples of 100–200 larvae each gave a maximum error in the average mortality of not more than 10 per cent, the exact number of samples depending upon how they were selected. Although no one series of samples gave a high degree of accuracy, it is believed that the large number of observations gives a fairly accurate basis for estimating the immediate effects of low temperatures upon overwintering western pine beetle broods.

Two hundred fifty-three of the samples were examined to determine the exact position of the overwintering brood in the bark.

The fatal low temperatures which occurred in December 1932 were remarkable for their long duration, lasting from December 7 to 17. The coldest day was the December 11, when −38° F was recorded at Meacham, Ore. A strong wind blew more or less constantly, resulting in a thorough agitation of the air so that similar temperatures prevailed over wide areas.

Mortality of western pine beetle broods, determined by a large series of bark counts made immediately following this freeze, are shown in table 2. Nearly as many more areas were represented in the sampling,

Table 4.—Brood mortality of *Dendroctonus brevicomis* late in the fall as a result of low temperatures in November 1935.

Areas in Oregon	Approximate Minimum Temp. ° F	No. Samples	No. Sq. Feet Infested Bark	Per Cent Brood Mortality
1. Klamath county (Keno district)	+ 2	49	23.9	6.8
2. Ochoco National Forest (Gerow Butte)	0	35	22.7	8.5
3. Fremont National Forest (Deming creek)	−13	44	25.9	38.8
4. Deschutes National Forest (Metolius area)	−15	41	23.6	43.8
5. Deschutes National Forest (Watkins Butte)	−20	42	18.2	56.8
6. Deschutes National Forest (Summit Stage station)	−20	42	16.1	60.7

but only those based on fairly adequate samples are included in the table. Killing was noted in Oregon and northeastern California, but there was very little in Washington, where temperatures were not so severe.

Cold weather in February 1933 was of much shorter duration, lasting only two to four days, but was of much greater intensity. An all-time record of −54° F was established for the state of Oregon. The distribution of the low temperatures was somewhat different from that of the December freeze and caused additional western pine beetle mortality in Oregon and Washington, but little, if any, in California. There was also killing in a number of areas, particularly in Washington, that had not been affected by the December freeze. Brood mortalities following the combined December and Februarv freezes are shown in table 3.

These mortality counts and other brood examinations showed some killing of western pine beetle broods in nearly all ponderosa pine forests east of the Sierra Nevada and Cascade ranges, from Lake Tahoe, in California, to northern Washington and presumably into Canada. Figure 1 shows the approximate distribution of light and heavy mortality in ponderosa pine stands affected by these two periods of low temperature. Light killing, or that of less than 50 per cent, occurred from the vicinity of Lake Tahoe to Modoc county, Calif., in small areas in Oregon, affected by the Klamath river and Columbia river climates, and in most of Washington. Heavy killing, or that above 50 per cent, occurred in

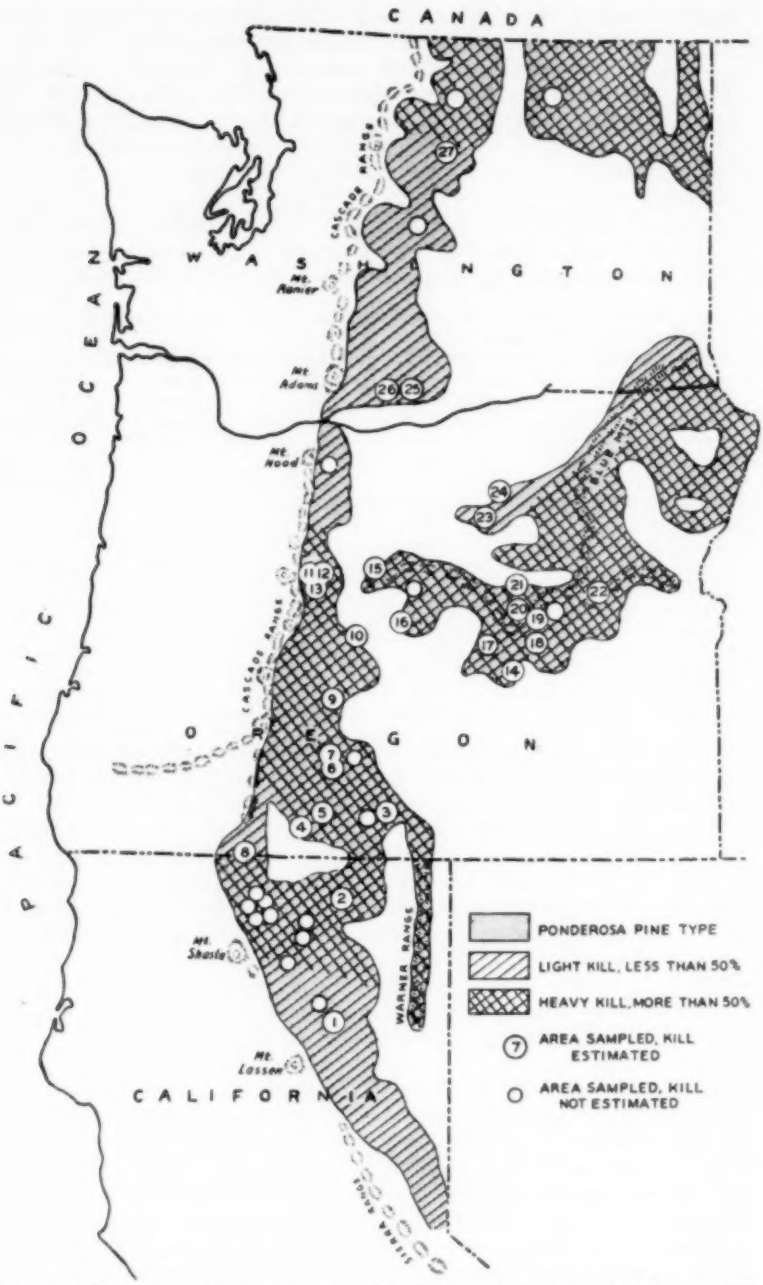

Fig. 1.—Winter kill of *Dendroctonus brevicomis*, December 1932 and February 1933.

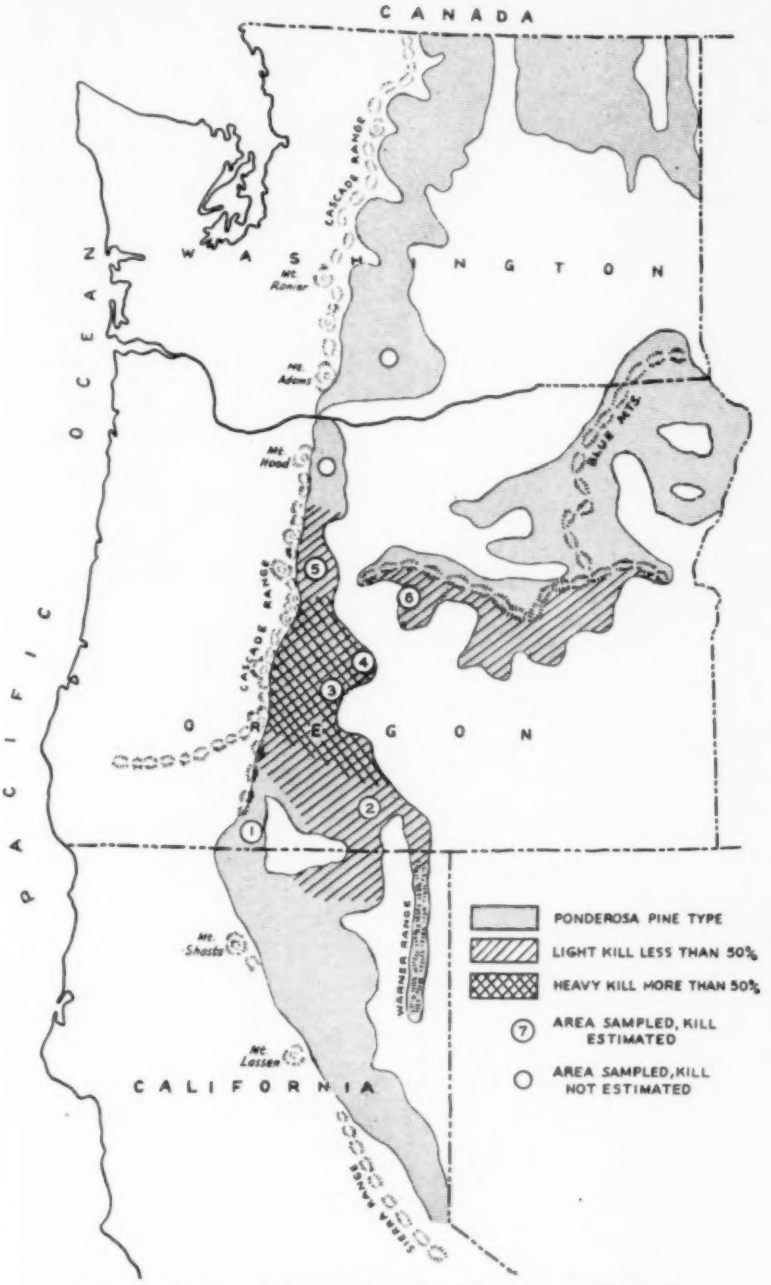

Fig. 2.—Winter kill of *Dendroctonus brevicomis*, November 1935.

Modoc and Siskiyou counties, Calif., southern and central Oregon, and the northernmost part of Washington.

Low temperatures occurring from the first to the fifth of November 1935, although rather severe in a few localities, were chiefly notable for their unseasonable character. A new early-season record of −27° F was established in Oregon. The brood mortalities following these unseasonable temperatures are shown in table 4. As indicated on the accompanying map (fig. 2), the effect of this cold period was more or less limited to

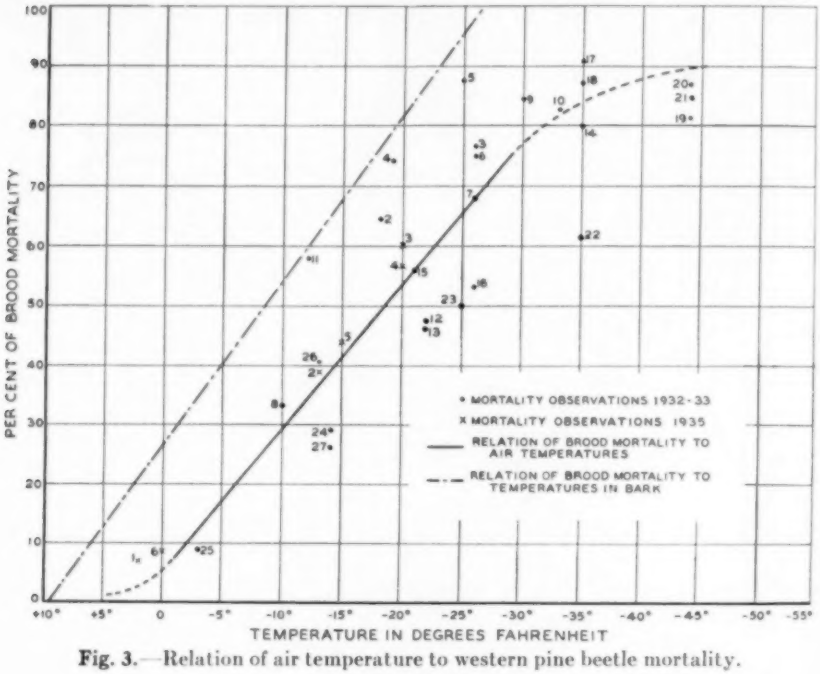
PER CENT OF BROOD MORTALITY
TEMPERATURE IN DEGREES FAHRENHEIT
+10° +5° 0 -5° -10° -15° -20° -25° -30° -35° -40° -45° -50° -55°
• MORTALITY OBSERVATIONS 1932-33
× MORTALITY OBSERVATIONS 1935
RELATION OF BROOD MORTALITY TO AIR TEMPERATURES
RELATION OF BROOD MORTALITY TO TEMPERATURES IN BARK

Fig. 3.—Relation of air temperature to western pine beetle mortality.

central and southern Oregon. Heavy killing was restricted to a relatively small area south and east of Bend, Ore. Perceptible killing occurred in the Modoc area of northeastern California, but there was little or no killing in the state of Washington.

The records of minimum temperatures and corresponding brood mortalities for the three periods of cold weather, given in tables 2 to 4, have been combined in graphic form, fig. 3, to show their general relationship. It is evident from this graph that, within rather broad limits, there is a definite relationship between minimum air temperatures and brood mortality. This information may be used as a rule-of-thumb method for determining the approximate western pine beetle kill when certain minimum air temperatures occur. The relative accuracy of determining brood mortality from minimum air temperatures at standard weather stations was tested after the November 1935 freeze. Six areas were sampled and the brood mortalities determined. These mortalities fell within 7 per

cent of the theoretical, which is sufficiently accurate for practical purposes.

It is fortunate that observations are available on the effects of these three periods of low temperatures, for they afford an opportunity to compare the effects of the three types of cold weather which would logically be expected to produce the greatest brood mortality, viz., a period of prolonged cold, a period of intense cold, and a period of unseasonable cold. Comparing the effect upon brood mortality of these three different types of cold weather periods, we find that for similar minima there is very little difference in the amount of kill, at least not enough to be significant within the wide fluctuations found when correlating brood

Table 5.—**Brood mortality of *Dendroctonus brevicomis* according to type of cold weather.**

Minimum Temperature	Per Cent Mortality			
°F	Average	Prolonged Cold December 1932	Intense Cold February 1933	Unseasonable Cold November 1935
−12	33	57.9		
−13	36		40.6	38.8
−14	38	29.3	26.1	
−15	40			43.8
−19	51	74.1		
−20	52			56.8
−20	52			60.7
−21	55	56.1		
−22	58		47.	
−22	58		46.1	
Average deviation		*+10.1*	*−7.5*	*+4.9*

mortality with local weather station temperatures. Table 5 gives the basis for this comparison.

While not sufficient to be conclusive, there is some evidence from table 5 to indicate that, given the same minimum temperatures, prolonged cold is somewhat more effective than brief or unseasonable cold. Unseasonable cold also causes slightly higher mortality than the average; while a short cold period is not quite so effective as the other two. The difference in effect of prolonged cold as contrasted with cold of short duration may result from differences in the temperatures which are produced under the bark. Greater effectiveness of unseasonable cold may be due more to brood conditions than to temperature factors.

In the 1932–33 freeze, slight regional differences in cold resistance of broods were noted. A higher mortality (65 per cent at −19° F)was found on the Modoc, Calif., area than where similar temperatures occurred farther north. This may indicate either a difference in regional strains of beetles or merely a difference in method of sampling.

Modifying factors.—The effect of low temperatures upon western pine beetle broods under field conditions depends upon several important factors, particularly the temperature to which broods are exposed, the environmental conditions surrounding them, and the condition of the broods. Since each of these factors is influenced by several variables, there is a complex relationship to consider in determining the amount of

mortality that results from a given air temperature. In studying the effects of recent low temperatures, these variables have been given special consideration in order to evaluate the importance of each.

TEMPERATURES.—The lack of a close degree of correlation between air temperatures and brood mortality, as indicated in fig. 4, is undoubtedly due in large measure to the fact that weather station air-temperature records do not apply closely to local forest conditions. Only a few of the low-temperature records of the three cold periods were taken in ponderosa pine stands. Usually the weather stations were in communities located in open valleys where minimum temperatures dropped somewhat lower than in nearby forests. Therefore it is difficult to determine what actual temperatures prevailed over the varied topography from which bark samples were taken, but for lack of better information the weather stations records had to be used even though they applied only approximately. Additional work is being done to correlate weather station records with air temperatures in the woods.

Subcortical temperatures to which broods are exposed depend on the air temperatures in the forested area modified by the insulating properties of the bark. Beal (1934) has shown, from studies in central Oregon, that there is a definite relationship between air and bark temperatures. During cold weather subcortical temperatures do not fall as low as those of the air, the differences being governed chiefly by bark thickness and the rate of temperature change. Not only is there a difference of as much as 29 Fahrenheit degrees between air and subcortical temperatures in bark of varying thickness, but there is a lag of one to two hours in the reaction of bark temperatures to air-temperature changes.

Since bark thickness plays such an important part in modifying subcortical temperatures, it is of interest to know the proportions of bark of various thicknesses which are normally found on infested ponderosa pines in forests of this region. Fortunately, it is possible to determine this by a series of calculations from available data. The typical distribution of bark-thickness classes for all infested ponderosa pines on average site IV[4] stands in Oregon and Washington is shown in table 6. These percentages apply fairly well to all stands in which mortality records have been taken in this study.

Table 6.—Amount of bark of various thicknesses infested by *Dendroctonus brevicomis*, ponderosa pine, site IV, Oregon.

BARK THICKNESS, INCHES	PER CENT OF TOTAL BARK SURFACE
$\frac{1}{2}$ or less	.9
$\frac{5}{8}$ to 1	67.
$1\frac{1}{8}$ to $1\frac{1}{2}$	27.7
$1\frac{5}{8}$ to 2	3.6
$2\frac{1}{8}$ and more	.8

It will be noted from table 6 that nearly 95 per cent of all bark is from five-eighths to $1\frac{1}{2}$ inches in thickness. Therefore, what happens to broods in bark of from five-eighths to $1\frac{1}{2}$ inches thick is of the greatest consequence in determining the results of cold weather in any area.

Since the amount of insulation which the bark affords is directly dependent upon the amount of bark covering the brood, exact measurements were made in the winter of 1935 of the position of 19,885 large

[4] A classification used by foresters to designate stands reaching an ultimate average height of between 103 and 130 feet.

larvae in bark of different thicknesses. The average amount of insulating bark over large larvae in each bark-thickness group is shown in table 7. The protective bark covering over eggs and small larvae was calculated from 10,162 of these measurements, where large larvae lay adjacent to the phloem, by adding one-eighth inch for phloem thickness. By multi-

Table 7.—Amount of insulating bark over brood of *Dendroctonus brevicomis* in Oregon, midwinter 1935.

Total Bark Thickness	Per Cent of Large Larvae per Inches of Insulating Bark												Basis Number of Individuals
Inches	⅛	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2	
½ or less	29.3	48.9	20.2	1.6									2829
⅝ to 1¼	24.	27.	27.4	16.9	4.2	.5							9547
1⅜ to 2	18.4	18.6	15.8	20.8	14.7	8.3	3.1	.3					4801
2⅛ and more	12.2	12.3	10.6	12.8	11.1	15.9	12.1	9.8	2.	.5	.6	.1	2708
Weighted Averages, Large Larvae*													
All bark thicknesses	27.3	41.4	22.	6.6	1.8	.6	.2	.1					19,885
Weighted Averages, Eggs and Small Larvae*													
All bark thicknesses	9.4	33.2	39.4	12.6	3.7	1.1	.4	.1	.1				10,162

* Weighted for proportion of different bark-thickness classes found under average forest conditions; see table 6.

plying the per cent occurrence of brood in each bark-thickness group by the relative abundance of that bark-thickness group on all infested trees (from table 6), weighted averages were determined which show the relative amount of insulating bark over eggs and large larvae under field conditions. Insulation over these stages represents the extremes in variation. Since no brood stage can have more bark covering than the egg stage it can be assumed that in central Oregon more than 95 per cent of the overwintering brood are protected by 1 inch or less of bark, table 7.

Table 8.—Proportion of overwintering *Dendroctonus brevicomis* brood subjected to various subcortical temperatures, given a minimum air temperature of −26° F. (Adapted from Beal.)

Inches of Insulating Bark	Per Cent of Total No.		Spread Between Air and Bark Temperatures	Temperatures to Which Brood is Subjected	Lag of Bark Temperature Behind Air Temperature
	Large Larvae	Eggs and Small Larvae	°F	°F	
½ or less	68.7	42.6	8°	−18°	1 hour
⅝ to 1	28.6	52.	18° to 21°	−5° to −8°	1 hour
1⅛ to 1½	2.4	4.8	22° to 27°	+1° to −4°	2 hours
1⅝ to 2	.3	.5	26° to 29°	+3° to 0°	2 hours
2⅛ and more	0.	.1	No data	No data	No data

As an example of the insulating effect of ponderosa pine bark, data obtained by Beal (1934) can be used in conjunction with the information in table 7. The resulting table 8 shows the minimum temperatures to which various proportions of brood were subjected when the minimum air temperatures dropped to −26° F. Two features stand out: first, that more than 95 per cent of the brood has 1 inch or less of insulating bark covering, which gave a protection of 8–21°; and second, that a high degree of protection was given to a small percentage of the brood protected by thick bark. This latter, no doubt, is one of the factors contributing to the continuation of the species in those parts of its range

where extremely low temperatures are common. It must be kept in mind that this is a particular case and that bark of a certain thickness does not afford a fixed amount of protection to the underlying brood. Difference between air and subcortical temperatures varies considerably, being influenced primarily by the rate of change of air temperature. The more prolonged the cold, the less the difference between air and bark temperatures; however, extreme minima in the range of the western pine beetle do not last long so that there is always considerable differential between the lowest air temperature and that in the bark where brood is located.

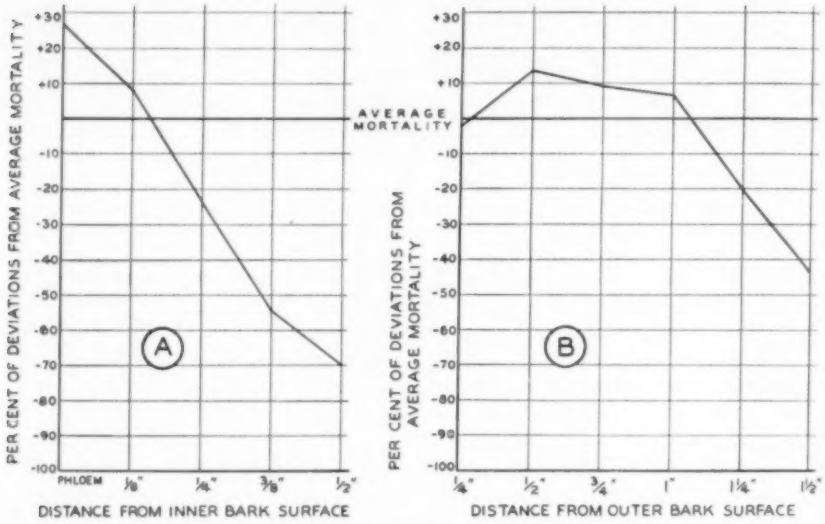

Fig. 4.—Larval mortality of the western pine beetle as influenced by position in bark. Basis 19,885 large larvae. *A*, in relation to inner surface; *B*, in relation to outer surface.

That this protection afforded by insulating layers of bark influences the amount of brood mortality during periods of extremely cold weather has been shown in all of the studies made so far. In general, as stated by Miller (1933) and Beal (1934), brood mortality varies inversely as the thickness of the bark in which the brood overwinters—*i.e.*, the thicker the bark the less the mortality.

Total bark thickness, however, is only a rough measure of the amount of insulating bark over the brood. In order to evaluate the effect of insulation more exactly, the mortality percentages among the 19,885 large larvae, previously referred to, have been arranged in graph form, fig. 4, B, in relation to the thickness of insulating bark over the brood. This arrangement shows a decrease in mortality with an increase in insulation, except for insulation of less than one-half inch. Mortality for brood with the least amount of insulation, one-quarter inch, falls decidedly and consistently out of line in all of the four areas sampled. This indicates, apparently, that some factor other than the amount of insulation is ef-

fective in reducing the amount of winter kill for the more exposed larvae. No ready explanation occurs to account for this exceptional condition.

ENVIRONMENTAL FACTORS.—Analysis of bark samples subsequent to the 1932–33 low temperatures showed an important variation in the proportion of brood mortality according to the height on the tree. On four areas trees were felled and sampled at intervals along the trunk. The average mortality, as shown by basal samples alone, was found to be 14.8 to 23.5 per cent less than when the entire tree was sampled, table 9. Even when bark of the same thickness was compared, it was found that mortality would be practically uniform in the upper portion of the trunk but considerably greater than that at the base (5 to 20 feet above the ground). The reason for this is not well understood but it may be due to a difference in bark character or brood condition.

Table 9.—Average mortality of western pine beetle in total and basal bark, all thicknesses, Oregon, 1932–33.

AREA	PER CENT MORTALITY		
	Total Bark	Basal Bark	Difference
Klamath Indian Reservation	84.2	69.4	14.8
Deschutes National Forest, area 1	81.	63.	18.
Deschutes National Forest, area 2	74.6	52.2	22.4
Ochoco National Forest	53.	29.5	23.5
Average			*19.7*

Brood mortality is consistently greater on the north than on the south side of infested trees, following periods of very cold weather. This is well illustrated by a statistical analysis of the difference of mortality on the north and south sides of 145 trees sampled in the winter of 1932–33. In this comparison, mortality on the north was found to be 30 per cent greater than that on the south side, and, since the standard error of sampling was only 4 per cent, the difference is certainly significant.

Higher mortality occurred on the north side despite the fact that the bark was on the average one-eighth of an inch thicker than on the south side. (This difference in bark thickness on the north and south sides of the trunk appears to be characteristic of ponderosa pine and is probably the result of greater weathering on the south side.) Two possible reasons may account for the higher mortality on the north side. Minimum temperatures reach about the same level on both sides, but on bright days temperatures do not rise as rapidly or as much on the north as on the south side; therefore, the duration of cold is much longer on the north. The second consideration is that because of generally colder conditions on the north side, brood does not develop as rapidly as on the south side. Overwintering larvae are smaller and in addition the bark is tighter and more moist. As will be shown later, these conditions have a pronounced effect in increasing the mortality.

In all series of bark samples that have been examined to determine brood mortality, differences in amount of mortality have been observed to be associated with differences in bark character. A much higher survival has been repeatedly noted in soft, spongy bark as contrasted with hard, flinty bark. This can hardly be explained as due to a difference

in insulating properties, since the diffusivity, upon which insulation depends, is practically the same for all ponderosa pine bark. It seems more likely that the visible differences in bark character reflect certain differences of moisture content and available food for bark beetle development. These factors would have an important bearing upon the physiological resistance of individual larvae to low temperatures, which in turn would be reflected in different mortality rates.

That there is a definite relationship between amount of mortality and nearness of brood to the inner bark was noted following the freezes of 1932–33 and 1935. In general, the closer the brood to the inner bark surface, the greater the amount of mortality, and this in spite of the fact that brood in the inner bark is protected by the greatest amount of bark covering. It is of interest, therefore, to determine where the bulk

Table 10.—Position of overwintering large larvae of *Dendroctonus brevicomis* in relation to the inner bark surface, Oregon, 1935.

Bark Thickness Group	Per Cent of Large Larvae by Distance in Inches from Inner Bark Surface								No. Larvae
Inches	Phloem	One-eighth	One-quarter	Three-eighths	One-half	Five-eighths	Three-quarters	Seven-eighths	
1 or less	25.9	60.3	12.1	1.4	.3				2829
1⅛ to 1½	19.7	52.2	21.	5.	1.5	.4	.2		9457
1⅝ to 2	15.2	50.	22.7	7.1	3.7	.9	.4		4801
2⅛ and more	11.3	44.5	27.6	9.1	4.9	1.5	.7	.4	2708
Weighted averages	*23.7*	*57.5*	*15.1*	*2.7*	*.8*	*.1*	*.1*		*19.885*

of overwintering brood is located with reference to the inner bark and the importance of this factor in determining mortality.

Small larvae, as has been pointed out, confine their activity to the moisture-laden, highly nutritious phloem region. Exact measurements of the position of 19,885 large larvae, in the samples already referred to, showed that 99 per cent of the overwintering large larvae occur within three-eighths inch of the inner bark surface. Of these, 23.7 per cent are in contact with, but rarely within, the phloem, table 10.

The relative mortality of brood in relation to proximity to the inner bark surface was determined following the low temperatures of November 1935. This relationship for bark of all thicknesses is shown in fig. 4, A. The basis for this graph is the same as for fig. 4, B, except that the measurements were taken to the inner bark surface instead of to the outer surface. A direct relationship is quite evident in that mortality decreases rapidly with increased distance from the inner bark.

Larvae living in the phloem region have the greatest amount of insulation, yet the mortality of this group was decidedly higher than that of the larvae living farther out in the bark. Therefore, larvae near the phloem must succumb at higher temperatures than those in the outer bark, for the insulating effect of bark thickness has already been demonstrated. In this connection it was noted that in thick bark the larvae tend to occur in the phloem much less frequently than in thin bark (see table 10), which might partially account for the lower mortality to brood in thick bark.

During the examination of samples it was recognized that large larvae tend to be distributed in the bark in two characteristic patterns. In one type the brood is concentrated in or very close to the phloem, and,

more often than not, these larvae are smaller than average in size. Brood mortality is high in samples of this kind. In the second type, brood occurs in scattered fashion, but is chiefly well removed from the phloem. In samples of this latter type, larvae are of normal development and the relative mortality is low. Insufficient samples were available for statistical analysis of these tendencies, but from general observation the difference appeared to be quite marked.

That there is considerable difference between inner and outer ponderosa pine bark, both as to moisture and nutrient content, has been demonstrated in previous experiments. Jeffrey, in unpublished studies, found that food in the form of sugars is more abundant in the phloem than in the outer bark. Moisture content of the inner bark has been found to be six or seven times as great as that of the outer bark. It is altogether likely that the physiological condition of larvae feeding under these varying conditions of inner and outer bark would be differently affected, resulting in a corresponding difference in their reaction to low temperatures.

Table 11.—Per cent mortality of small larvae of the western pine beetle as compared to average mortality of all larvae from the same areas and bark of the same thickness, Oregon, 1932–33.

Average Mortality All Larvae	Mortality of Small Larvae	Increased Mortality Among Small Larvae
74.5	100.	34.2
72.9	96.4	32.6
72.7	100.	37.5
72.7	100.	37.5
72.7	100.	37.5
54.7	100.	82.9
54.7	100.	82.9
40.8	100.	145.
38.7	100.	158.5
32.9	88.	167.5
32.9	100.	204.
16.5	100.	505.
16.5	43.7	165.
Average		*130.*

Miller (1931) and Beal (1927, 1933) have shown that environmental moisture plays an important rôle in determining the resistance of *Dendroctonus* broods to low temperatures. Miller found that *D. brevicomis* larvae in saturated bark succumb to temperatures 10 degrees higher than do larvae from normal bark. Since moisture is such an important factor influencing brood resistance, it is not surprising to find that those larvae living closest to the inner bark surface suffer the highest mortality.

Samples containing work of cerambycid beetles (chiefly *Acanthocinus spectabilis* Lec.), which tends to dry out the bark and decrease its moisture content, were observed to have relatively lower bark beetle mortality from freezing than samples having no cerambycid work. As considerable variation existed among the samples, however, conclusions based on statistical analysis were not possible.

Brood Conditions.—Investigations in Oregon during the winters of 1932–33 and 1935–36 point to the conclusion that small larvae are less resistant to low temperatures than are large larvae. Miller (1933) reported the reverse to be the case in California during 1932–33, although subsequent examinations showed that practically no brood developed from those trees that contained small larvae at the time the low temperatures occurred.

Variations in larval size are closely associated with differences in en-

vironmental moisture and kind or condition of the food—differences which have been considered responsible for differences in cold-hardiness. As has been pointed out, the small larvae live in or near the phloem, while most of the large larvae are in the outer corky bark. Proximity to the inner bark surface has been shown to increase the amount of brood mortality, so that it is logical that mortality at a given temperature is greater among small larvae than among large larvae, table 11.

For some time it has been recognized that there is a stunted development of larvae in certain trees, probably caused by adverse conditions of an undetermined nature within the bark. In examining bark samples

Table 12.—Effects of low temperature upon western pine beetle populations, winter of 1932–33.

Forested Area	Brood per Square Foot of Infested Bark		Per Cent of Brood Killed in Midwinter	Per Cent of Reduction from Normal* Emergence	Per Cent of Reduction in Volume of Timber Losses, 1932 to 1933
	Living Larvae Following Freeze	Emergence in Spring 1933			
Malheur National Forest	61	3	83	97	57
Bly area	44	11	83	90	75
Fremont National Forest	65	5	81	95	61
Modoc National Forest	103	†	65	†	33
Ochoco National Forest	83	21	57	81	60
Deschutes National Forest	92	29	54	74	23
Lassen National Forest	164	†	46	†	9
Rogue River National Forest	143	21	33	81	50

* Normal emergence considered 112 beetles per square foot, based on emergence counts for mild winters of 1930 and 1931.
† No comparable data taken to show spring emergence.

to determine mortality, especially in the winter of 1935–36, it was evident time and again that samples containing small individuals, but undoubtedly in the third and fourth instars, would exhibit a much higher degree of mortality than those samples containing brood of normal size. This tendency has also been noted in laboratory studies at Berkeley, Calif.

The tightness of the bark in infested trees is dependent very largely upon the degree of development of the brood; in general, the younger the brood, the tighter the bark. Since trees with tight bark contain the younger brood stages, it follows that brood mortality in these trees is higher than in those trees with loose bark. Observations in Oregon have supported this conclusion.

Subsequent effect of winter killing.—The ultimate emergence of overwintering western pine beetle broods following the cold winter of 1932–33 was determined by emergence counts. These have been used for many years as a method of sampling populations of *Dendroctonus brevicomis*, since the emergence holes of the progeny can be distinguished from the entrance holes, ventilation holes and emergence holes of the parents. A characteristic of the emergence holes of progeny is that they do not

connect directly with the egg galleries, as do the other types. While it has been found that approximately $1\frac{1}{4}$ beetles emerge per hole, the number of holes does give an index of the relative abundance of the emerging populations.

During the summer of 1933, emergence counts of 3500 square feet of bark were taken on some of the same areas where brood mortality counts had been made during the winter. For uniformity, samples were taken as follows from trees 16 to 30 inches in diameter at breast height: (1) 15 to 25 feet above ground, (2) in bands around the trees so that all sides were equally represented, (3) to include normal attacks only, (4) to include

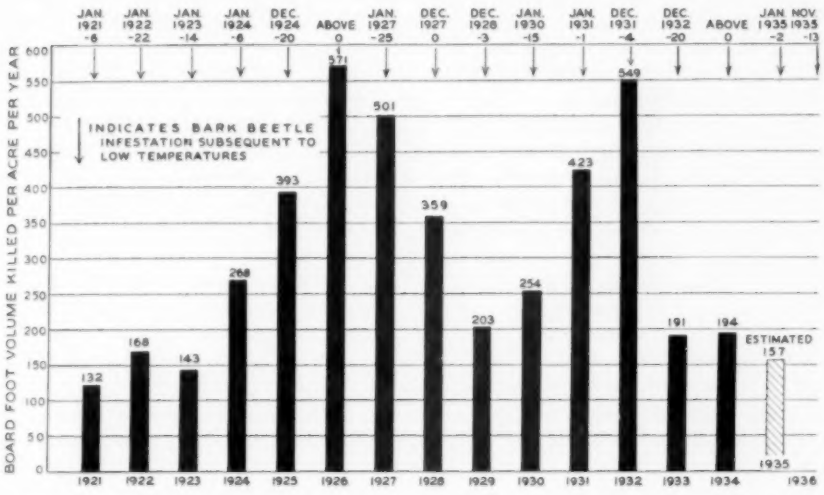

Fig. 5.—Infestation trend of the western pine beetle and occurrence of minimum temperatures, southern Oregon. Basis: Eleven 640-acre plots.

bark of average thickness only. Under these conditions of sampling it was found that 15 to 20 square-foot samples from each of as many trees were sufficient to insure a maximum error in the average of not more than 10 per cent. This method of sampling was applied to six areas in Oregon where over 3000 of the samples were taken.

Counts in central and southern Oregon showed that the emergence in the spring of 1933 was less than 20 per cent of that normally occurring following mild winters in the same area, table 12. Approximately the same amount of reduction was noted in northern California, although the basis for estimates was not the same as in Oregon. No estimate was made of spring emergence in areas where there had been light winter mortality.

Supplementing the emergence counts, emergence from 165 square feet of infested bark on 29 ponderosa pines that were subjected to low temperatures was determined in the spring of 1933 by caging portions of the infested trees. This was done in central Oregon and northern California. The screen type of cage used in this work has been described and

illustrated by Buckhorn (1936). These caging experiments showed that, while the average emergence was greatly reduced, a considerable residue of living beetles remained in the bases of some trees. These living beetles, which occurred mainly in trees with thick bark, were to be found only in the basal portion of these trees, usually in the first 10 feet.

Subsequent reinfestation.—The after-effects of the winter killing, as indicated by the amount of infestation that developed during the 1933 season, were judged from timber cruises to determine the amount of insect-killed ponderosa pine on 86 sample plots, totalling 24,180 acres. The plots, of 320 or 640 acres each, are located in California, Oregon and Washington. Many of them have been cruised annually for the last 15 years to determine the amount of insect-caused losses (primarily those from *Dendroctonus brevicomis*). A comparison of the timber losses on these plots is the best available means of determining the status of infestation during any one year. The reduction of infested tree volume in 1933, on areas where considerable winter mortality occurred, is shown in table 12. It is evident from these data that the 1933 infestation was considerably less than that of 1932, but that total reduction for the year was not always in proportion to the winter killing that had occurred.

Effects upon predatory insects.—The effect of low temperatures upon the insect enemies of *Dendroctonus brevicomis* is of importance as it affects their abundance relative to their host. Not much information is available on this point, but the following observations have been made: cermabycid larvae, mostly those of *Acanthocinus spectabilis* Lec., which destroy some brood of the western pine beetle by competing with them for space and food, are affected by low temperatures to about the same extent as are the bark beetles. The clerid *Enoclerus lecontei* Wolc., which is the most important insect enemy of the western pine beetle, is not so resistant to cold as is its host. This is relatively unimportant, however, for most of the clerid larvae migrate to the soil at the base of the tree, where they are protected from the low temperatures. From general observations in the spring of 1933, the indications are that the clerid increases in relation to its host in seasons following low temperatures. The ostomatid *Temnochila virescens* var. *chlorodia* Mann., which is a predator of some importance, is killed by about the same temperatures as *E. lecontei*, but since it does not migrate to the same extent, it suffers a higher mortality. *T. virescens chlorodia* was observed to be scarce in the spring of 1933.

Control considerations.—The fact that low temperatures may cause widespread killing of western pine beetle broods immediately raises the question as to its importance in controlling outbreaks of this beetle. If low temperatures wipe out epidemics, there is little reason for spending large sums on control work following their occurrence. In order to determine the effects of winter killing upon epidemics, it is only necessary to observe the infestation trends in seasons following periods of low temperatures. For this purpose, much information is available from annual cruises of timber losses on sample plots.

The record of western pine beetle infestation in southern Oregon since 1921 may be taken as an example. The fluctuations in volume[5] of timber

[5] While the board-foot losses in timber volume on these plots are indicative of the relative abundance and

killed per acre on 7040 acres of plots cruised each year in the area between Klamath Falls and Lakeview, Ore., is shown in fig. 5, together with the extreme minimum temperatures at a typical point in the area. Consideration of this graph shows that there has been no very noticeable effect of cold weather in halting beetle epidemics. The one exception appears to have been the very pronounced reduction in 1933, following the cold weather of the preceding winter. The effects of this cold apparently acted in the same direction as the infestation trend and served to accelerate the decline.

In central Oregon cold weather is more frequent and more intense than in southern Oregon, which may explain why large areas of overmature ponderosa pine in just the right condition for beetle attack have escaped injury for so long a time. Unfortunately, no continuous record of the infestation in this area is available, so the actual effects of low temperatures cannot be determined.

The evidence so far would indicate that, in cases where a high percentage of brood is killed, this does have an effect in reducing subsequent infestation of the western pine beetle for a period of about one year, but anything less than a 50 per cent kill of brood has little or no effect upon the general trend of western pine beetle epidemics. It is clear that even a severe reduction of brood by cold weather has no lasting effect upon epidemic trends and that these trends are primarily influenced by other factors.

Exceptionally low temperatures, then, do not always make artificial control measures unnecessary, although in certain years their effect may justify an alteration of plans. A brood reduction by freezing of 50 per cent or more is considered necessary to cause alteration of control work in the year of the low temperatures. To date, three control projects have been influenced by the effects of low temperatures upon western pine beetle broods. In 1932–33, control work on the Modoc National Forest, Calif., was stopped after it was partially completed, as a result of a 65 per cent winter kill (Miller 1933). The same winter, control work on the Ochoco National Forest, Ore., was suspended after there had been a 50 per cent mortality from freezing. In 1935 a proposed project on the Deschutes National Forest, Ore., was abandoned because of a 50 to 60 per cent winter kill of the western pine beetle. During these two winters three control projects were completed, although some winter killing had occurred in the areas treated. In the spring of 1933 a small project was completed in the Warner mountains, Calif., after a winter kill of 50 per cent. This was a border-line case where control operations probably would have been abandoned had there not been the hope of achieving a complete clean-up of infestation in a small area. In December 1935 two projects were completed after a 30 to 50 per cent winter kill in November of the same year. One of these projects was near Bly in southern Oregon and the other near Sisters on the Deschutes National Forest, Ore.

economic importance of the western pine beetle from year to year they are not an absolute measure of the population. Several other insect species, including *Melanophila californica* VanD., *Ips emarginatus* (Lec.), *Ips oregoni* (Eich.), and *Dendroctonus monticolae* Hopk., contribute to the seasonal losses on the plots, but killing by the western pine beetle constitutes the major part of the infestation—especially in years of epidemic losses. The entire problem of sampling the western pine beetle population is an important one, deserving of detailed consideration, which cannot be given here.

The effectiveness of winter killing, like that of artificial control, depends only upon numerical reduction of the beetle population without modifying the factors that tend toward an increase of the species. Therefore, if the other underlying factors which govern the abundance of the insect are not altered to its detriment in the mean-time, it is necessary to maintain the temporary reduction of the population from year to year until the time when economic losses are slight or until the timber crop has been harvested. Winter killing, then, can be made use of in certain seasons to replace artificial control, but it must be clearly recognized that its effectiveness is of short duration.

Since winter killing may at times replace artificial control, it is necessary, in order to take advantage of its help, to recognize when such killing has occurred. This should present no great difficulty because winter killing of regional importance is caused only by widespread temperatures of $-15°$ F or lower. Since in the range of the western pine beetle such low temperatures are readily recognized by their unusual nature, there is little likelihood that they will be overlooked now that their importance is realized. From study of weather records, the general distribution and probable degree of winter killing may be estimated, since the approximate relation of air temperatures to mortality has been determined from this study, fig. 4. Field investigations of the local effects of the low temperatures should then be made to verify these estimates.

Summary.—The western pine beetle, *Dendroctonus brevicomis* Lec., a bark bettle destructive to ponderosa pine throughout its Pacific coast range, is influenced to a large extent, both in distribution and seasonal abundance, by low winter temperatures. As a transition zone species, it is well adapted to the temperatures that normally occur in its range. Toward its southern limits there is no winter killing from low temperatures, but from central California northward winter killing occurs from time to time.

Normal mortality from the egg to the adult stage is 85 per cent, most of which takes place during transformations. Overwintering broods, made up mostly of large larvae but including a few small larvae, eggs and adults, suffer a normal mortality of about 5 per cent during the hibernation period when no transformations occur. During extremely cold winters, killing of a large percentage of the overwintering brood may take place. Sometimes this reduction of brood closely approximates 100 per cent.

The three following periods of cold weather have been investigated in this study: a period of prolonged cold in December 1932, a short period of intense cold in February 1933, and a period of unseasonable cold in November 1935. The combined cold of December 1932 and February 1933 caused some western pine beetle mortality in practically all ponderosa pine stands east of the Sierra Nevada and Cascade ranges from central California to Canada. Mortality as a result of the November 1935 cold weather was limited to central and southern Oregon. The data, although not conclusive, indicate that, given the same minimum temperatures, the prolonged cold was most effective, the unseasonable cold less effective, and the brief cold least effective in reducing western pine beetle populations.

Several factors influence the amount of brood mortality that will result at given air temperatures. These factors act by modifying the actual temperatures to which the broods are exposed, by changing environmental conditions, or by influencing the cold-hardiness of individuals in the brood.

Bark thickness is of importance in modifying the subcortical temperatures to which brood is actually exposed. In general, mortality from freezing varies inversely as the thickness of the insulating bark over the brood, although the correlation is not good for insulation of less than one-half inch.

Winter killing at the base of trees averages 19.7 per cent less than the general average for the entire tree. Above the base, the mortality rate is uniform for bark of the same thickness.

Winter killing decreases rapidly with increased distance from the inner bark—that is, the farther the brood from the inner bark, the less the amount of mortality. This is a straight-line relationship that gives a better correlation to mortality than does amount of insulation.

Small larvae are less resistant to low temperatures than are large larvae; brood in trees with tight bark is less resistant to freezing than brood in trees with loose bark; brood on the north side of a tree suffers higher mortality than that on the south; abnormally small larvae succumb sooner than normal larvae; all probably for the same reason, for in each case the less resistant brood exists under conditions where the amount of moisture is greater. Environmental moisture is known to be an important factor influencing cold hardiness.

Sampling in the spring of 1933 showed that the emerging population was less than 20 per cent of that following mild winters. The residual population, however, exhibited a decided tendency toward increase so that in some localities the 1933 infestation was nearly as great as that of 1932. However, for the entire area affected the 1933 infestation was lower than in 1932, and considerably lower than it otherwise would have been, as indicated by the general infestation trend.

In general, the effects of low temperatures are not evident in the infestation trend except in extreme instances, about once in 10 years, when the course of infestation may be altered for about one year. The cold weather of 1932–33 was an example of this kind. Anything less than 50 per cent reduction has little or no effect upon the annual infestation; therefore, this amount of kill, or more, is necessary to cause alteration of artificial control work. Three control projects have been influenced by the effects of cold weather, two in 1932–33 and one in 1935–36.

The amount of winter killing can be estimated with a fair degree of accuracy from minimum temperatures at standard weather stations, depending upon how closely the weather station records apply to the forested area in question. Such estimates of amount of winter kill are of importance in determining the necessity for artificial control during winters having extremely low temperatures. It is considered necessary to check the accuracy of the estimates in the field before recommending modification of control work.

In general, cold weather affects the insect enemies of the western pine beetle to about the same degree as the host.—4-26-37.

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AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

PAPER-READING SESSION, FORTY-EIGHTH ANNUAL MEETING

St. Louis, Mo., December 1935

Testing for Resistance to American Foulbrood in Honeybees

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Over a period of 20 years occasional honeybee colonies have been reported as possessing either immunity or resistance to American foulbrood. Among the first to report such cases should be named Herman Rauchfuss of Colorado, John M. Bixler of Iowa and Bruce Lineburg of Illinois. Within the last few years similar reports have come from Charles Mraz of Vermont, Erwin C. Alfonsus of Wisconsin, R. G. Richmond of Colorado and others.

In general, such reports have been received with incredulity by teachers and research workers in the field of apiculture, and by most well-informed beekeepers, whose attitude is epitomized in the expression: "Interesting, if true." Not that there was any doubt as to the veracity of those who made these reports, but rather that we were totally unprepared to accept at face value anything so wholly contradictory to our training in regard to the inability of bees to rid themselves of American foulbrood. It had been drilled into us from our earliest contact with beekeeping literature that bees positively could not remove scales of American foulbrood, and that once the disease was contracted, the colony was doomed.

But claims regarding resistance have recurred so persistently that they can no longer be ignored. Either there is truth in these claims or there is not. The matter is too vitally important to the beekeeping industry to permit a continuation of the present status of uncertainty, with no attempt to clarify the situation. If resistant bees exist, we cannot begin

[1] Journal paper J325 of the Iowa Agricultural Experiment Station, Ames, Iowa; project 448.

too soon to propagate them; if they do not, the sooner we find it out, the better.

Resistant strains sought.—A search for bees resistant to American foulbrood began in 1935 as a project of the Iowa Agricultural Experiment Station. Three agencies are cooperating in this work: the entomology section of the Agricultural Experiment Station, the Agricultural Extension Service of Iowa State College, and the *American Bee Journal*. The extension service is represented by the state apiarist, Prof. F. B.

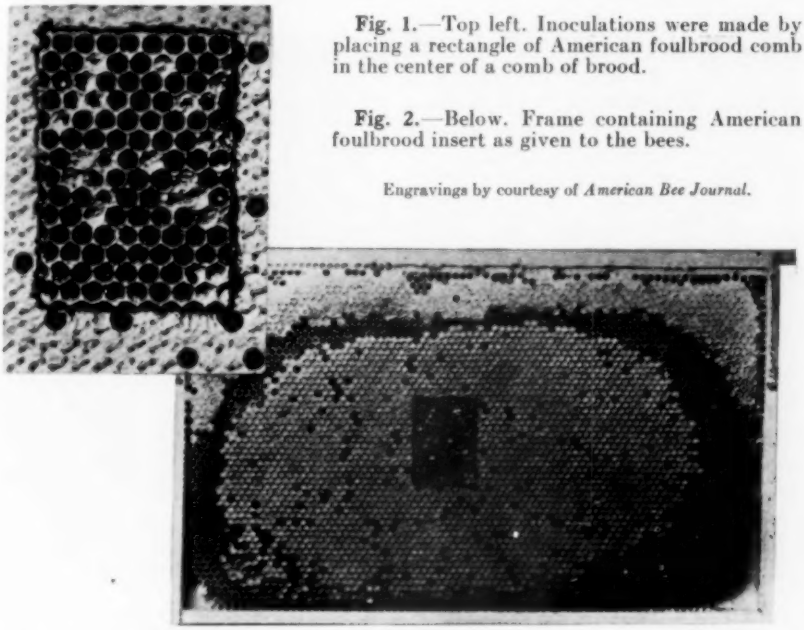

Fig. 1.—Top left. Inoculations were made by placing a rectangle of American foulbrood comb in the center of a comb of brood.

Fig. 2.—Below. Frame containing American foulbrood insert as given to the bees.

Engravings by courtesy of *American Bee Journal*.

Paddock, who in connection with his regular duties is constantly on the lookout for stock that gives promise of being disease-resistant. The *American Bee Journal* is represented by its field editor, Frank C. Pellett who acts as apiarist and collaborator. The entomology section is represented by the writer, who is in charge of the technical phases of the project.

While the ultimate goal of this investigation is the development and propagation of a resistant strain, our immediate objective has been to answer the question: *Does variation in resistance to American foulbrood exist in honeybees?* Obviously a negative answer would mean that there is no possibility of breeding a resistant bee, while an affirmative answer would give reason to expect some degree of success. The scattered cases reported as showing resistance suggest a probability that some colonies possess resistance to a greater degree than do others, but conclusive evidence is needed.

In brief, our plans for determining whether variation in resistance to

American foulbrood exists were to obtain supposedly resistant stock from every possible source, bring such colonies together in one place and inoculate them with uniform doses of the disease.

A testing yard, established with the approval and under the regulations of the state apiarist, was located on the Frank C. Pellett farm near Atlantic, Iowa. To this yard were brought 45 colonies that were suspected of possessing some degree of resistance to American foulbrood. Among them were representatives of Italian, Caucasian and Carniolan races, besides several hybrid strains. They came from many sections of

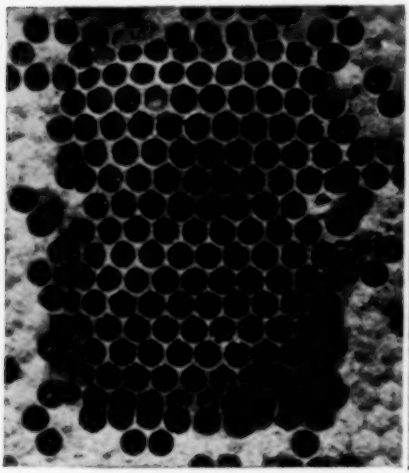

Fig. 3.—Insert after four days, repaired and cleaned. Colony apparently disease-free September 28.

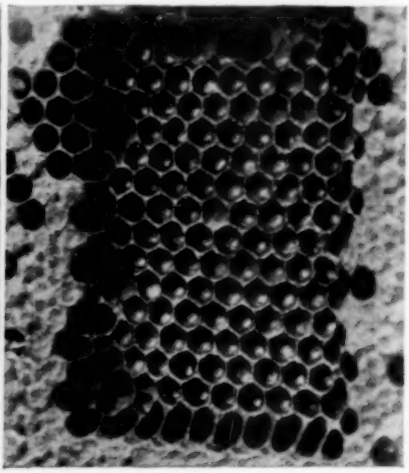

Fig. 4.—Insert after three days, cell walls removed to midrib. American foulbrood present September 28.

the United States and were furnished gratis. In some instances the beekeeper even prepaid transportation charges. It is evident, therefore, that beekeepers are interested in this investigation and are anxious to cooperate in this organized search for resistant stock.

Technic of test.—Two methods were considered for administering uniform doses of the disease. The first consists in feeding sirup or honey in which is suspended a given number of spores of the causal organism, *Bacillus larvae*. This method has been used by Dr. A. P. Sturtevant and by Prof. R. G. Richmond in this country and by Prof. H. O. Muck in Austria. It has often failed to produce the disease, whereas Prof. Muck reports that the following method has rarely failed. A rectangle of comb is removed from the center of the brood nest and is replaced by a similar rectangle cut from a comb containing numerous scales of American foulbrood.

The latter method was selected for our work. The rectangles used were approximately 2 by $2\frac{1}{2}$ inches and contained about 200 cells, of which approximately half held scales of American foulbrood, figs. 1 and 2. No inoculation comb containing less than 75 scales was used. Any

colony that is able to withstand such a dose surely must possess more than ordinary resistance.

Combs used in making inoculations were taken from a single source. This was done in order to eliminate any variation which might result if material from more than one source was used. The potency of the organism in this material can scarcely be doubted since it came directly from an apiary that only recently had been wiped out by American foulbrood. Furthermore, results of inoculations made during the past season indicate no lack of potency.

In order to obtain a fair test, it was considered that the colony should occupy eight or more *Modified Dadant* brood combs and that at least 75 per cent of its adults should be the progeny of the queen then heading the colony. And since this stock came to us as queens, as nuclei and as combless packages, several weeks elapsed before any of it was ready for inoculation. Only 25 of the 45 received built up in time to be tested the same season. In addition to the 25 supposedly resistant colonies inoculated, six check colonies were tested, making a total of 31 inoculations. The check colonies were from ordinary stock and were not supposed to be resistant. In fact, previous experience with stock from the same sources indicated probable susceptibility.

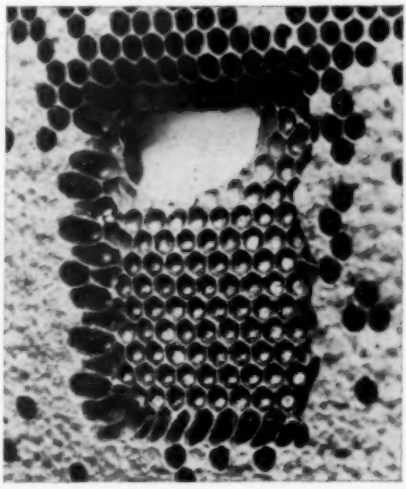

Fig. 5.—Insert after four days, cell walls and part of midrib removed. Bad case of American foulbrood September 28.

All inoculations were made during the first three weeks of August. Frequent examinations were made during the week following inoculation in order to observe the behavior of the bees toward the insertions. Cells of American foulbrood usually were present by the end of the third week, and whenever they were found samples were taken for final determination under the microscope. By the time the last examination was made, on September 28, two to three cycles of brood had been reared since the inoculations were made. Brood-rearing was still in full progress in most of the colonies, although in a few it had been reduced somewhat.

While final results of these tests cannot be known before another year, it is believed that sufficient information has been secured to warrant this preliminary report.[2]

Reactions of bees.—Observations made a few days after inoculation combs were given revealed wide variations in the way different colonies

[2] During the year that has elapsed since the above report was rendered, five more of the colonies inoculated in 1935 have eradicated all symptoms of the disease, bringing the total to 12, or practically half of the 25 presumably resistant colonies inoculated in 1935. Of the seven reported disease-free at the end of the first season, the disease reappeared in one, but not until after a swarm had issued, thus placing a different queen at the head of the colony.

reacted toward these rectangles of comb containing American foulbrood scales. Some colonies accepted the inoculation comb, fastened it securely in place, repaired damaged cells and proceeded to clean out the scales. A case of this kind is pictured in fig. 3, as it appeared four days after being inserted.

Other colonies tore away the cell walls as shown in fig. 4, and some removed portions of the midrib also, as may be seen in fig. 5. A few days later it was found that in such cases the cell walls had been reconstructed of new wax on the old midrib.

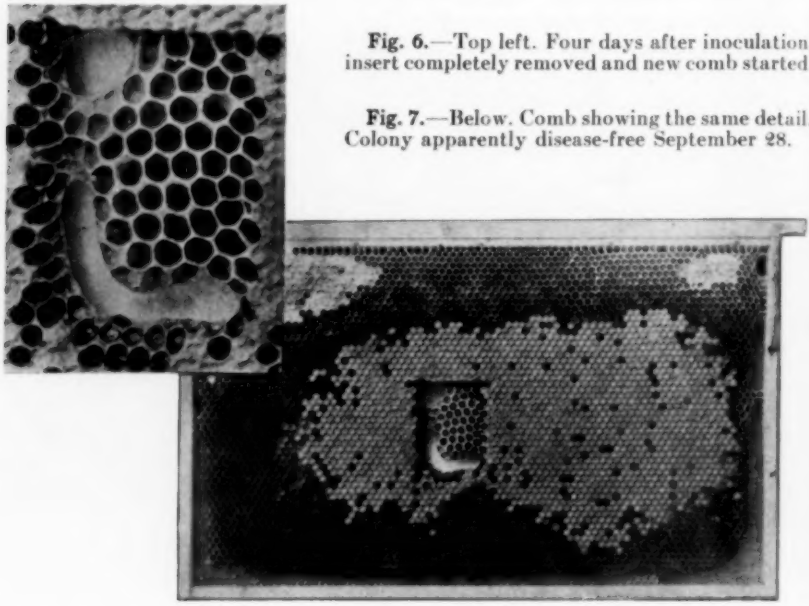

Fig. 6.—Top left. Four days after inoculation, insert completely removed and new comb started.

Fig. 7.—Below. Comb showing the same detail. Colony apparently disease-free September 28.

Still others removed every vestige of the inoculation comb and completely rebuilt with new wax. Figures 6 and 7 illustrate such instances. Notice that the bees made use of this opportunity to build drone cells and that the queen lost no time in laying eggs in them. Figure 8 shows a similar case. The inoculation comb was given August 2 and when this picture was taken, four days later, the inoculation comb had been removed completely. New comb already occupied the space except for a circular area about three-fourths of an inch in diameter, as may be noticed. In fig. 9 this same comb area is shown as it appeared on the seventh day after inoculation, completely rebuilt and containing young brood and fresh nectar. On August 20, three weeks after inoculation, dozens of cells of American foulbrood were found in a fan-shaped area spreading out below the place where the inoculation comb had been. The explanation for this seems to be that spore-laden particles must have fallen into these cells while the bees were tearing down the inoculation comb. By September 15 the bees had removed every trace of dead larvae,

and subsequent examinations have revealed none. On September 28 the comb inoculated eight weeks before appeared as shown in fig. 10. It may be observed that no indication of disease is to be seen. Even the very cells that had contained larvae dead of American foulbrood on August 20, now held brood which, to all appearances, was healthy.

Checking up on bee behavior.—Do bees behave differently toward comb containing American foulbrood scales than toward other, similar old comb? This question naturally arises, and so the bees were asked to answer it. Their answer may be discovered by looking at figs. 11, 12

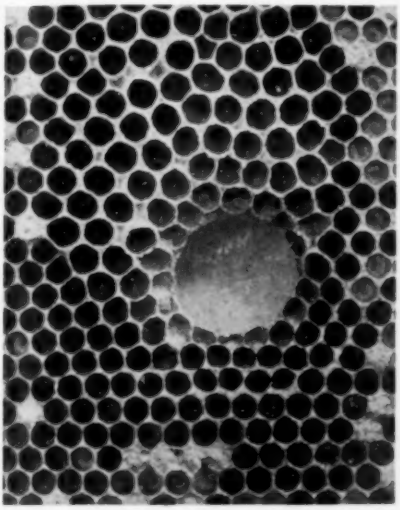

Fig. 8.—Insert completely removed after four days and new comb nearly completed. Colony apparently disease-free September 28.

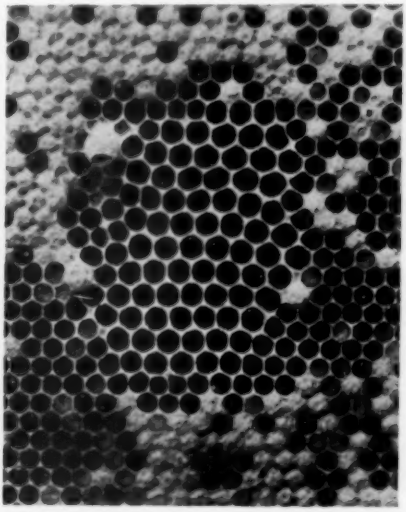

Fig. 9.—Same as fig. 8, but taken three days later.

and 13. Figure 12 shows a frame of brood containing two rectangular pieces of old black comb inserted within the brood area. A closer view of these inserts is shown in fig. 11. The insert at the left, as may be judged from the picture, contained scales of American foulbrood, while the other was disease-free. In this condition, the frame was returned to its hive. Figure 13 shows the appearance of these same inserts three days later. All that remained of the diseased comb was a part of the midrib, but the other insert had been accepted without alteration. Seven other colonies were subjected to this kind of a test, and every one of them removed a considerable part of the diseased insert, but in no case was the disease-free insert altered. It is apparent, therefore, that bees do not reject inserts of comb merely because they are inserts, but rather because of some objectionable feature such as the presence of American foulbrood scales. At any rate, it is a significant fact that some colonies tear down and remove comb that is infected with American foulbrood.

Results.—An attempt has been made to classify, according to their

behavior, all colonies that were inoculated during the season. Three fairly distinct groups have been recognized as follows: Group I, colonies that accepted the inoculation comb with little or no alteration. Figure 3 shows a typical example. Group II, colonies that tore down cell walls but did not remove the entire comb. Examples are shown in figs. 4 and 5. Group III, colonies that completely removed the inoculation comb. An example is shown in fig. 6.

It is to be understood that there were several intermediate cases which presented some difficulty in exact classification, but for the sake of simplicity each of these was assigned to the group it most resembled.

Results of this classification are tabulated below.

	Groups		
	I	II	III
Total colonies	12	15	4
Apparently disease-free Sept. 28	3	1	3
Disease-free colonies as percentage of group	25	7	75

Detailed records enable us to classify still further the colonies that accepted the inoculation comb. Some did a poor job of cleaning out the foulbrood scales, and subsequent records show that they became badly infected before the close of the season. On the contrary, three colonies that did a thorough job of cleaning out the scales were found apparently free from disease on September 28.

Only one of the 15 colonies that tore down the cell walls to the midrib was found apparently free from disease on September 28. Since five of the six check colonies belong in this group (the sixth belongs in group I), there is reason to wonder whether this type of behavior may be more or less characteristic of colonies that are susceptible to American foulbrood.

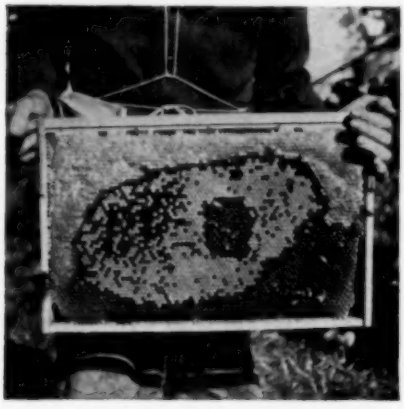

Fig. 10.—Same as figs. 8 and 9, taken September 28, eight weeks after inoculation. Colony apparently disease-free.

Three of the four colonies that completely removed the inoculation comb were found apparently free from disease on September 28.

In all, seven of the colonies tested were found apparently free from disease before the end of the season. This group includes representatives of several races and various strains of bees.

Whether resistance to American foulbrood is the result of better housekeeping, as is believed to be the case in strains resistant to European foulbrood, or depends upon physiological factors, or both, remains to be determined. Observations reported above suggest the possibility that good housekeeping methods may play an important rôle, but, judging from what we think we know about bacteria in general and *Bacillus larvae* in particular, it scarcely seems possible that such measures alone could enable a colony to reduce the disease to zero as appears to have

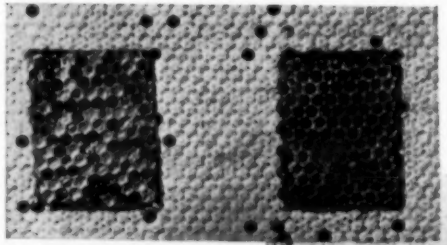

Fig. 11.—Above. American foulbrood insert at left, disease-free insert at right.

Fig. 12.—Below. Full comb showing same two inserts; left, American foulbrood; right, disease-free.

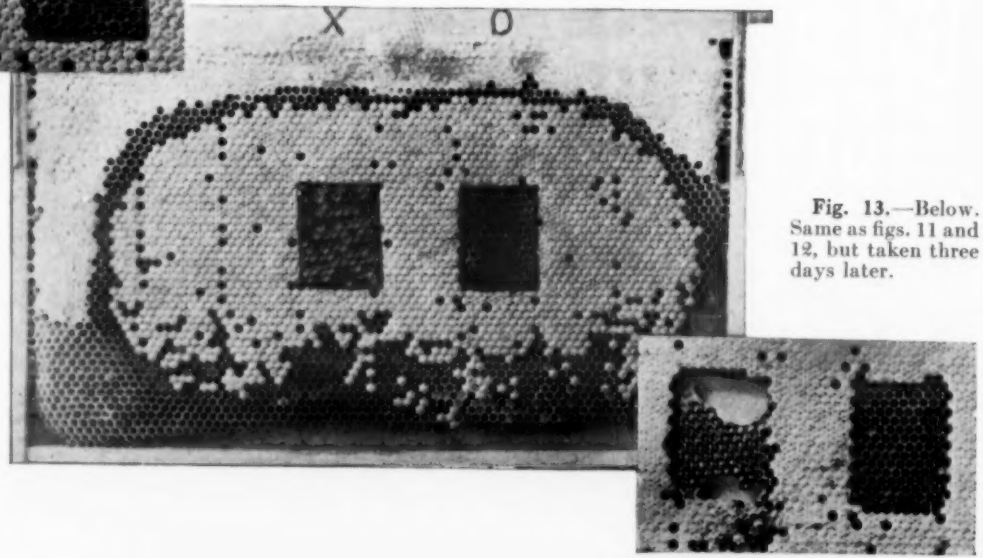

Fig. 13.—Below. Same as figs. 11 and 12, but taken three days later.

been done. Evidences are not entirely lacking, however, to indicate the probability that physiological resistance is involved. One such evidence is the fact that a considerable proportion of the affected brood in resistant colonies did not die until it had reached the pupil stage. Some factor—probably physiological—enabled these individuals to withstand the infection longer than is the rule. In general the percentage of infected individuals that reach the pupil stage in non-resistant colonies is very small—probably less than 1 per cent. Is it not, then, conceivable that some individuals in resistant colonies may withstand the infection with sufficient success to carry them on into the adult stage? It seems probable, therefore, that both behavioristic and physiological resistance are involved here.

The results of this investigation indicate not only that resistance varied in the colonies tested, but also that it varied over a wide range—from the highly susceptible check colonies to the seven highly resistant ones which apparently were disease-free on September 28. Not one of the check colonies showed noticeable ability to combat the disease, whereas nearly one-third of the colonies suspected of possessing more or less resistance demonstrated their ability to clean up the disease within a few weeks—a very high order of resistance.

Summarizing, we find that 31 colonies were inoculated. American foulbrood became well established in all six of the check colonies and in several of those supposed to be resistant. Of 25 supposedly resistant colonies tested, seven were found apparently free from disease on September 28. Of these seven, all but one are known to have developed more or less American foulbrood following inoculation.

In conclusion it may be stated that the immediate objective of this investigation has been attained, in that variation in resistance to American foulbrood has been demonstrated. And since marked resistance was shown by a number of colonies, we are encouraged to believe that we may eventually reach our ultimate goal, a strain of bees that will breed true for resistance.—3-22-37.

CURRENT CONTRIBUTIONS

Improved Control of Red Spider on Greenhouse Crops

With Sulfur and Cyclohexylamine Derivatives

C. C. COMPTON and C. W. KEARNS,[1] *Illinois Natural History Survey, Urbana*

More than 100 years ago the insecticidal properties of sulfur were recognized. Since that time various sulfur compounds have been experimented with as insecticides and "acarinacides." Kenrick (1833) devised a sulfur–quicklime mixture which was probably the first attempt at

[1] Investigator, Crop Protection Institute. Publication of this paper has been secured by payment of the printing charge.

making lime sulfur. The value of calcium sulfide, one of the essential compounds in lime sulfur solutions, has been recognized as an acarinacide. More than 25 years ago Quayle (1912) used lime sulfur against spider mites. McGregor (1912) found potassium sulfide to have value against the red spider, *Tetranychus telarius* (L.), on cotton.

More recently, potassium–ammonium–seleno–sulfide has been extensively used for the control of red spiders. The proprietary mixture *Selocide*, containing 8 per cent potassium–ammonium–seleno–sulfide, is effective in killing all stages of the red spider, including the egg, when used at a 2 per cent dilution. Certain proprietary mixtures of organic thiocyanates have also been used and found toxic to all stages of the red spider. The fact that the aforementioned compounds cannot be used with safety on all greenhouse crops at dilutions effective against red spiders prompted the investigation herein reported.

This paper is submitted as a progress report in the hope that it will aid other workers in the problem of control of red spiders and related mites. The tests reported in this paper are based on the average per cent of mortality in five to 30 tests for each material and concentration used.

Acarinacide effectiveness varies with crops.—Greenhouse roses suffer very severe damage through the feeding of the common red spider. Studies made during the last five years show that this mite causes losses in excess of half a million dollars to greenhouse roses in Illinois annually. In addition, very severe damage is inflicted on other greenhouse crops, practically all of which are subject to attack. The problem of controlling red spiders on roses is complicated by the fact that not only are the mites particularly difficult to kill, but the foliage is easily injured by most chemicals. Acarinacides used at dilutions which will give 100 per cent kill of the common red spider on such crops as chrysanthemums, carnations or snapdragons, will have almost no effect on the same species on roses. Increasing the concentration of the spray frequently results in injury to the plants. Just why red spiders are so difficult to control on roses has not been fully determined. The texture of the leaf surfaces of the rose is such that a relatively small amount of spray is retained on the foliage. Reducing the amount of spreader in the spray will reduce the run-off but results in failure to wet the spiders sufficiently to get a kill. It has also been demonstrated that red spider from rose is more resistant to most acarinacides than the same species of red spider from many other crops.

Space will not permit discussion of this point in detail but in the way of example, 50 adult female red spiders were removed from snapdragons and a like number from talisman rose and placed on cotton cloth. Each lot was sprayed with a measured amount (4 cc.) of spray. The spray used was *Selocide*, .25 per cent with the addition of *Aresket* 240 at .2 per cent concentration. One hundred per cent of red spiders from snapdragon were killed while only 2 per cent of the mites from rose were killed. Increasing the concentration of *Selocide* to 1 per cent gave 100 per cent kill of the red spiders from snapdragon, but only 36 per cent kill of the mites from rose was obtained. Similar results were obtained with the other materials tested. *T. telarius* from rose, sweet pea, carnation, ageratum, lantana and snapdragon have been used in these tests.

The spiders from rose proved the most resistant, while those from snapdragon were least resistant to acarinacides. This would indicate that extreme care should be exercised in comparing the results of acarinacides applied to red spiders on different crops.

So far as greenhouse work is concerned, acarinacides which will give a high degree of control on rose without injury to the plants can be used effectively and safely on the majority of greenhouse crops.

Results of ammonium polysulfide tests.—During the last two years ammonium polysulfide has been tested against the common red spider. This sulfide was prepared by the senior author by saturating ammonium hydroxide, 28 per cent NH_3, with hydrogen sulfide and dissolving sulfur in the ammonium sulfide solution. Various amounts of sulfur were used in the solution, ranging from 10 to 20 per cent by weight. The majority of tests herein reported were made with ammonium sulfide in which was dissolved 10 per cent of sulfur. Unless otherwise stated, the ammonium polysulfide referred to hereafter contains 10 per cent sulfur. Greater amounts of sulfur do not materially add to the toxicity of the polysulfide and result in increased danger of injury on certain plants. Ammonium sulfide in which 20 per cent of sulfur is dissolved leaves a heavier residue of sulfur on the foliage, which may be considered to have a residual effect on red spiders but on many ornamentals leaves an unsightly discoloration. Additional sulfur slows down the volatilization of ammonia and ammonium sulfide and tends to increase the danger of injury. The percentage of kill obtained on such outdoor crops as raspberry, perennial phlox, asters, hollyhocks, morning glory and dahlias is very high. The residual effect of additional sulfur on the foliage against red spider is not great enough to compensate for the danger of plant injury.

The results obtained outdoors were so promising it was hoped that this sulfide could be used to advantage in the greenhouse.

The use of ammonium polysulfide in the greenhouse, however, is limited by the fact that the gases evolved from the polysulfide solution are toxic to certain plants, notably rose, sweet pea, and chrysanthemum. Begonias were not injured by repeated applications of the spray. The foliage of roses is not burned at weak concentrations, .5 per cent or lower, but the action of the gases causes the more mature leaves to turn yellow and drop prematurely. Roses have been sprayed without injury with ammonium polysulfide at .25 per cent concentration when the house has been well ventilated during the time of spraying and for several hours afterwards. Ammonium polysulfide at this concentration exhibits low toxicity to red spiders unless supplemented by the addition of gums, as shown later. There is less danger of injury when a few plants or a single bench of plants is sprayed, than when the entire house is sprayed. This is because the gases from the spray solution are more concentrated when the entire house is sprayed. It is well known that yellowing and premature dropping of rose foliage may be caused by ammonia. Hydrogen sulfide is also a contributing factor. McCallan, Hartzell & Wilcoxon (1931) have shown that hydrogen sulfide is responsible for injury to certain plants when the plants exposed to daylight are subjected to concentrations of hydrogen sulfide as low as 20–40 p.p.m. for five hours. It has been

demonstrated (Marsh, 1929; Liming & Young 1930; McCallan & Wilcoxon 1931; McCallan, Hartzell & Wilcoxon 1936) that when sulfur is applied to leaves of plants hydrogen sulfide is produced. McCallan & Wilcoxon (1931) have shown that hydrogen sulfide is toxic to fungus spores. We have demonstrated in the laboratory that hydrogen sulfide is very toxic to red spiders. It is apparent that hydrogen sulfide is the most toxic agent evolving from sulfur and sulfides. All stages of the red spider, including the egg on rose and snapdragon plants, have been killed by subjecting them to a relatively high concentration of hydrogen sulfide for a relatively short exposure. The plants were fumigated in darkness

Table 1.—Relative toxicity of ammonium polysulfide, potassium sulfide and *Selocide* to red spiders on outdoor crops.

Test No.	Materials Used	Per Cent Dilution	Per Cent Kill of Red Spiders on					
			Raspberry	Hollyhock	Morning Glory	Dahlia	Phlox*	Aster
1	Ammonium polysulfide† *Grasselli Spreader*‡	1. .125	98	97	98	99	95	96
2	*Selocide*	2.	99	98	98	96	96	97
3	*Selocide* *Grasselli Spreader*	1. .125	94	93	95	94	95	95
4	Ammonium polysulfide† *Grasselli Spreader*	.5 .125	98	98	99	94	94	100
5	*Selocide* *Grasselli Spreader*	.25 .125	27	43	36	27		
6	*Grasselli Spreader*	.125	12	15	9	7		
7	Potassium sulfide *Grasselli Spreader*	1. .125		79	80			
8	Potassium sulfide *Grasselli Spreader*	.5 .125		68	72			
9	Potassium sulfide *Grasselli Spreader*	.25 .125		21	30			
10	*Selocide*	.5		15	13	9	9	12

* Perennial Phlox. † Prepared with 10 per cent sulfur by weight. ‡ *Grasselli Spreader*, formerly *SS-3*.

without injury. This phase of the investigation will be reported on in a later paper.

While injury has occurred to certain greenhouse plants as outlined above, the test plants used outdoors have not been injured. Raspberry, perennial phlox, aster, hollyhock, morning glory and dahlia were sprayed during the summer of 1936, at temperatures ranging from 70 to 100° F, with ammonium polysulfide at concentrations as high as .5 per cent, without a trace of injury. These tests have not by any means been exhaustive, but they indicate that in the open air gases from the ammonium polysulfide solution dissipate so rapidly that injury to the plants is prevented and the residue left is not sufficient to cause injury through the liberation of ammonia, hydrogen sulfide and other toxic agents. Our tests have also indicated that for best results a relatively high temperature (above 75° F) and low relative humidity (below 40 per cent) are required. It should also be stated that a good wetting agent is essential. In the tests herein recorded, *Aresket 240* at .2 per cent and *Grasselli Spreader* at .125 per cent have given excellent results.

Aside from the sulfides and other compounds containing sulfur in their molecules, certain derivatives of cyclohexylamine have been found to be highly toxic to red spider. Kearns & Flint (1937) reported the N,N-

amyl-acetyl and N,N-amyl-benzoyl derivatives of cyclohexylamine as being toxic to red spiders. These two compounds were tested upon red spiders infesting various crops and found to be highly toxic to red spiders and safe to apply to most outdoor crops. They could not, however, be used at concentrations sufficient to produce a satisfactory control of red spider upon certain greenhouse crops without producing injury. In the meantime, a new derivative of cyclohexylamine known as *C.P. 100* has been developed by the Monsanto Chemical Company, which is more toxic to red spiders and possesses a greater margin of safety to plants than either of the two previously mentioned derivatives. This latter compound has been tested to a considerable extent in the laboratory upon red spiders infesting a large variety of plants and has thus far proved to be safe at concentrations necessary to produce kills

Table 2.—Relative toxicity of ammonium sulfide, ammonium polysulfide potassium sulfide and *Selocide* to red spider on greenhouse plants.

Test No.	Materials Used	Per Cent Dilution	Per Cent Kill of Red Spider on					
			Rose	Sweet Pea	Carnation	Snapdragon	Lantana	Ageratum
1	Ammonium polysulfide*	1.						
	Aresket 240	.2	47	92	80	97	91	93
2	Ammonium polysulfide†	1.						
	Aresket 240	.2	46	94	84	95	90	90
3	Ammonium sulfide‡	1.						
	Aresket 240	.2	20	16	12	46	39	43
4	Ammonium polysulfide§	1.						
	Aresket 240	.2	26		79	92		
5	*Selocide*	2.	98	99	100	100	100	100
6	*Selocide*	1.						
	Aresket 240	.2	21	76	70	96	98	98
7	Ammonium polysulfide*	.5						
	Aresket 240	.2	77	92	81	100	100	100
8	Ammonium polysulfide†	.5						
	Aresket 240	.2	79	89		100		
9	Ammonium sulfide‡	.5						
	Aresket 240	.2		40				
10	Ammonium polysulfide§	.5						
	Aresket 240	.2	26		62			
11	*Selocide*	.5						
	Aresket 240	.2	15	19	29	100		
12	Ammonium polysulfide*	.25						
	Aresket 240	.2	27	75	67	100	87	86
13	Ammonium polysulfide†	.25						
	Aresket 240	.2	31	75				
14	Ammonium sulfide‡	.25						
	Aresket 240	.2	7					
15	Ammonium polysulfide§	.25						
	Aresket 240	.2	25	67				
16	*Selocide*	.25						
	Aresket 240	.2	17	18	20	90	86	20
17	*Selocide*	.25	11	13	10	48		
18	Potassium sulfide	1.						
	Aresket 240	.2	62	63	68	100		
19	Potassium sulfide	.5						
	Aresket 240	.2	37	43	38	100		
20	Potassium sulfide	.25						
	Aresket 240	.2	20	27	21	89		

* Prepared with 10 per cent sulfur by weight. † Prepared with 20 per cent sulfur by weight.
‡ NH_4OH saturated with H_2S without sulfur.
§ Ammonium polysulfide manufactured by Shell Oil Company under following specifications: free NH_3 1.5 per cent by weight; free $(NH_4)_2S$ 11.9 per cent by weight; free sulfur 21.3 per cent by weight.

closely approximating 100 per cent. It has been tested to considerable extent in commercial greenhouses upon several varieties of rose, with results agreeing with those obtained in laboratory tests except for several instances where slight injury to rose was encountered.

C.P. 100 is colorless, viscous, liquid, insoluble in water but soluble in various petroleum and vegetable oils. It may be prepared in a form readily miscible with water by the use of a sulfonated codfish oil commercially known as *Albasol*. A solution containing 70 per cent *C.P. 100* and 30 per cent *Albasol* was found to be readily miscible, and very stable in aqueous solutions. The toxicant was miscibilized in this manner in all the tests recorded in this paper.

Table 3.—Toxicity of *C.P. 100* solutions upon red spiders infesting various crops.

Test No.	Materials Used	Per Cent Dilution	Per Cent Kill of Red Spiders on					
			Rose	Carnation	Lantana	Ageratum	Chrysanthemum	Verbena
1	70% *C.P. 100* + 30% *Albasol*	.33						
	Aresket 240	.2	98	100			100	
2	70% *C.P. 100* + 30% *Albasol*	.25						
	Aresket 240	.2	94	100	100	100		
3	70% *C.P. 100* + 30% *Albasol*	.2						
	Aresket 240	.2	74	92	100		98	100
4	70% *C.P. 100* + 30% *Albasol*	.125						
	Aresket 240	.2	32	70	99		89	
5	70% *C.P. 100* + 30% *Albasol*	.1						
	Aresket 240	.2	14	68	98	100		96
6	70% *C.P. 100* + 30% *Albasol*	.083						
	Aresket 240	.2	15	22		98	57	96
7	70% *C.P. 100* + 30% *Albasol*	.066						
	Aresket 240	.2	7	21	69	79	34	72
8	*Aresket 240*	.2	9	2	7	8	4	2

Relative toxicity on outdoor crops.—Growing plants of the crops listed in table 1 were sprayed with a 3-gallon compressed air sprayer, or with a power sprayer at 250 to 300 pounds pressure. The results obtained with low pressure and high pressure applications were approximately the same. In the case of raspberry and dahlia, tests were run on a field scale and the spray applied with a power sprayer.

Ammonium polysulfide at .5 per cent concentrations gave as good or better kill than *Selocide* (8 per cent potassium–ammonium–seleno–sulfide) at the same concentration with a spreader or *Selocide* at 2 per cent concentration without the addition of a spreader other than that contained in the prepared product. Ammonium polysulfide and *Selocide* gave a higher kill than potassium sulfide at the same concentration. No foliage injury occurred on any of the crops sprayed with ammonium polysulfide or *Selocide* at .5 per cent concentration. In several cases there was a trace of injury with ammonium polysulfide at the 1 per cent concentration on morning glory and aster. Potassium sulfide at concentrations greater than .33 per cent injured the young growing leaves of morning glory, dahlia and aster.

Relative toxicity on greenhouse crops.—Many species of plants other than those occurring in table 2 were sprayed. The plants listed in this table represent fairly well the various types of foliage encountered in the greenhouse. They also represent the range of red spiders as far as

tolerance to sulfide is concerned. Variation in tolerance of *T. telarius* on different host plants has been noted.

The toxicity of ammonium sulfide with 10 per cent sulfur, ammonium sulfide with 20 per cent sulfur, and ammonium sulfide without the addition of sulfur is compared with *Selocide* and potassium sulfide. Included in table 2 are the results obtained with a sample of ammonium polysulfide received in February 1937 from the Shell Chemical Company, Martinez, Calif. *Aresket 240* (40 per cent water solution) was used as a spreader at .2 per cent concentration. In a large series of tests, *Grasselli Spreader* (formerly *SS-3*) was used with practically the same results.

Ammonium polysulfide, potassium sulfide and *Selocide* exhibit a lower toxicity to red spiders on roses than to the same species on other plants, as shown in table 2. Ammonium polysulfide is more toxic to red spiders at a given concentration than *Selocide*. Its use in the greenhouse is limited, however, as we have noted. Potassium sulfide causes injury to rose, sweet pea, lantana and ageratum at concentrations greater than .5 per cent. The sulfides tested have a tendency to injure the flower petals, particularly on full-blown flowers. Flower buds or opening flowers are less likely to show injury.

Toxicity of *C. P. 100* solutions.—In table 3 the results of a series of tests made with *C.P. 100* are given. It will be noted that the same variation in the susceptibility of red spiders infesting different species of plants applies to *C.P. 100* as well as to *Selocide* and ammonium polysulfide, as previously pointed out. Roses were shown to be the most difficult among the plants tested to obtain a satisfactory control of red spider with *C.P. 100*. A concentration of .33 per cent of the solution containing 70 per cent *C.P. 100* and 30 per cent *Albasol* was found to be necessary to produce a mortality corresponding to that obtained with a 2 per cent concentration of *Selocide*. In contrast to the .33 per cent concentration of the *C.P. 100–Albasol* solution necessary to produce a satisfactory kill of red spider upon rose, the same approximate mortality was obtained upon red spider infesting ageratum with only .083 per cent concentration of the *C.P. 100–Albasol* solution.

There was just a single case of injury from these tests and that occurred when a .25 per cent concentration of the *C.P. 100–Albasol* solution was applied to ageratum. Lower concentrations did not produce injury and a satisfactory kill of red spiders may be obtained upon this plant with a .1 per cent concentration of the *C.P. 100–Albasol* solution.

Plants gums in red spider sprays.—Following the report of C. O. Eddy in his paper entitled "Karaya Gum in Nicotine Sprays," presented at Atlantic City, December 1936, the use of this gum and certain others with acarinacides has been investigated. The use of natural plant gums greatly increases the efficiency of the various sulfur compounds and other materials tested as acarinacides. By using gums in the spray solution the load of spray solution on the foliage can be greatly increased. Our tests indicate that it is possible to use lower concentrations of the toxicant and increase the margin of safety on the plants. Repeated applications of gum-bearing sprays have a tendency to coat or seal the leaf surface or to spot the foliage. In some instances there has been some yellowing of the lower leaves. It is thought that the regular greenhouse

practice of syringing with clear water at intervals can be utilized to remove the gum residue.

There is considerable variation in the different grades of Karaya gum. One lot of Karaya gum No. 1 which we worked with gave practically

Table 4.—Plant gums in red spider sprays.

Test No.	Materials Used	Per Cent Dilution	Per Cent Kill of Red Spider on			
			Rose	Carnation	Snapdragon	Lantana
1	Ammonium polysulfide*	.25				
	Aresket 240	.2				
	Karaya gum No. 3	.2	79	77	100	100
2	Ammonium polysulfide†	.25				
	Aresket 240	.2				
	Karaya gum No. 3	.2	56		100	100
3	*Lethane 440*	.25				
	Aresket 240	.2				
	Karaya gum No. 3	.2		94	100	100
4	*Loro*	.25				
	Aresket 240	.2				
	Karaya gum No. 3	.2		96	100	100
5	*Selocide*	.25				
	Aresket 240	.2				
	Karaya gum No. 3	.2	97	96	100	100
6	*Selocide*	.25				
	Aresket 240	.2				
	Karaya gum No. 1	.1	84	96	100	100
7	*Selocide*	.25				
	Aresket 240	.2				
	Locust-bean flour	.2	69	67	100	98
8	*Selocide*	.25				
	Aresket 240	.2				
	Lakoe A	.2	92		100	98
9	*Selocide*	.25				
	Arekset 240	.2				
	Lakoe X	.2	94		100	100
10	*Selocide*	.25				
	Aresket 240	.2	17	20	90	86
11	*Selocide*	.25	9	16	94	92
12	*Aresket 240*	.2	4	10	20	16
13	Karaya gum No. 3	.2				
	Aresket 240	.2	30	41	87	81
14	Water check		5	3	2	4

* Prepared with 10 per cent sulfur by weight.

† Ammonium polysulfide prepared by Shell Chemical Company. The material meets the following specifications: free NH_3 1.5 per cent by weight; free $(NH_4)_2S$ 11.9 per cent by weight; free sulfur 21.3 per cent by weight.

the same results at a concentration of .1 per cent as the No. 3 grade at .2 per cent concentration. In addition to Karaya gum, locust-bean flour, *Lakoe A*, *Lakoe X*, gum arabic and gum ghatti were tested. Locust-bean flour, gum arabic and gum ghatti did not give results comparable to the Karaya gum. *Lakoe A* and *Lakoe X* gave good results but are much more expensive than Karaya gum. The Karaya gum No. 3 and *Lakoe A*

have been reported to us as having a water-holding capacity of 50 times their weight, while the water-holding capacity of Karaya gum No. 1 and *Lakoe X* may run as high as 100 times their weight.

Because of the high water-holding capacity of these gums, considerable difficulty is experienced in getting them into a water solution. The best method we have found where the safety of the plants is considered

Table 5.—Toxicity of C. P. 100 and Karaya gum solutions upon red spiders infesting various plants.

Test No.	Materials Used	Per Cent Dilution	Per Cent Kill of Red Spider on					
			Rose	Carnation	Lantana	Ageratum	Chrysanthemum	Verbena
1	70% *C.P. 100* +30% *Albasol*	.2						
	Aresket 240	.2						
	Karaya gum No. 3	.1	97	99	100		100	
2	70% *C.P. 100* +30% *Albasol*	.125						
	Aresket 240	.2						
	Karaya gum No. 3	.1	72	99	99	100	99	100
3	70% *C.P. 100* +30% *Albasol*	.1						
	Aresket 240	.2						
	Karaya gum No. 3	.1	46	98	98	98		99
4	70% *C.P. 100* +30% *Albasol*	.066						
	Aresket 240	.2						
	Karaya gum No. 3	.1	27	61	97	96	68	99
	Check							
5	*Aresket 240*	.2						
	Karaya gum No. 3	.1	8.6	14	22	24	12	22
6	70% *C.P. 100* +30% *Albasol*	.2						
	Aresket 240	.2						
	Karaya gum No. 3	.125	99	99	100	100	99	
7	70% *C.P. 100* +30% *Albasol*	.125						
	Aresket 240	.2						
	Karaya gum No. 3	.125	99	99		100	99	100
8	70% *C.P. 100* +30% *Albasol*	.1						
	Aresket 240	.2						
	Karaya gum No. 3	.125	81	99			99	
9	70% *C.P. 100* +30% *Albasol*	.066						
	Aresket 240	.2						
	Karaya gum No. 3	.125	58	74	87	99	92	99
	Check							
10	*Aresket 240*	.2						
	Karaya gum No. 3	.125	22	31	36	32	28	32
11	70% *C.P. 100* +30% *Albasol*	.1						
	Aresket 240	.2						
	Karaya gum No. 3	.2	94	99	100	100	96	99
12	70% *C.P. 100* +30% *Albasol*	.066						
	Aresket 240	.2						
	Karaya gum No. 3	.2	78	87	92			99
	Check							
13	*Aresket 240*	.2						
	Karaya gum No. 3	.2	31	34	42	55	36	39

is to wet the gum with ethyl or methyl alcohol using alcohol at the rate of 250 cc. for each 4–6 ounces of gum. After throughly mixing the gum and alcohol, the mixture is poured slowly into the spray solution while agitating constantly. Best results are obtained if the spreader is added to the water first.

For laboratory work it is convenient to make up a stock solution. With Karaya gum No. 3 a 1 per cent solution is satisfactory. Heavier concentrations cannot be poured readily. The gum solution will spoil if allowed to stand for any length of time, but this may be prevented by adding .5 per cent formaldehyde to the suspension.

Karaya gum No. 3 was used at .1 to .2 per cent concentration in all tests recorded in tables 4 and 5. We feel, however, that for a high percentage of kill with the sulfides tested it is necessary to use the gum at .2 per cent concentration. With *C.P. 100* a .1 per cent concentration is satisfactory.

The relative toxicity of ammonium polysulfide, *C.P. 100*, *Lethane 440*, *Loro* and *Selocide* as influenced by the addition of several natural plant gums is shown. For example, in table 2, item 12, ammonium polysulfide (10 per cent sulfur) at a .25 per cent concentration, with a .2 per cent concentration of *Aresket 240* as a spreader, gave 27, 67, 100 and 87 per cent control of red spiders on roses, carnations, snapdragons and lantana respectively. Then in table 4, item 1, this same mixture with the addition of Karaya gum No. 3 at .2 per cent gave 79, 77, 100 and 100 per cent control on rose, carnation, snapdragon and lantana respectively.

Various concentrations of Karaya gum were tested with the *C.P. 100–Albasol* solution, as recorded in table 5. Here, as in the case of the previously discussed materials, addition of amounts of Karaya gum varying from .1 to .2 per cent to the spray solution greatly increased its toxicity. This increase in toxicity is caused not only by the greater quantity of the spray which the gum solution affixes to the leaf surface, but also may be due to the fact that it is capable of producing a high percentage of mortality when used without the presence of a toxic agent. This point is illustrated in tables 4 and 5, item 13, where mortalities ranging from 31 to 87 per cent were obtained.

Summary.—Toxicity of various compounds to red spiders infesting a number of greenhouse crops has been studied under laboratory, field and greenhouse conditions. Great variations in the susceptibility of red spiders to certain sprays has been shown to be closely correlated with the species of plant infested.

The materials tested were *Selocide* (8 per cent potassium-ammonium-seleno-sulfide), ammonium polysulfide, two organic thiocyanates (*Lethane 440* and *Loro*) and a derivative of cyclohexylamine produced by the Monsanto Chemical Company, known as *C.P. 100*. All of these materials were found to be effective and safe when applied to certain plants. Rose proved to be the most difficult plant on which to obtain a satisfactory control of red spider without causing injury to the plant. *Selocide* and *C.P. 100* have been the most successful in the control of red spiders infesting roses in the greenhouse.

The use of Karaya gum as an agent to increase the toxicity of red spider sprays has been found to be highly efficient in this respect.

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An Insect that Breathes Through Its Nose

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The trade commissioners of the Singapore station of the U. S. Department of Commerce, Bureau of Foreign and Domestic Commerce (World Trade Notes on Chemicals and Allied Products **5**(21):10. May 25, 1931) have reported an insect (probably a bostrychid beetle) found attacking stored derris root in British Malaya, as follows:

> Insect Thrives on Derris Root.—An insect in the Straits Settlements, described locally as a cross between a white ant and a coprabug, takes its nourishment from derris root. It is said that the insect breathes through its nose, thus making it immune from the toxic effects of the plant. This is reported as a factor in the deterioration of the product before shipment.

Journal writers also err.—This interesting contribution to insect physiology and insect genetics is matched by recent additions to our knowledge of chemistry offered by entomologists and recorded for the benefit of posterity in the pages of the Journal of Economic Entomology. In a recent issue of this Journal—the official organ of the American Association of Economic Entomologists—we read that "thiodiphenolamine," also known as phenothiazine, is a milky green substance and that, although it does not completely dissolve in diesel-engine oil and other oils, apparently the toxic element in it is soluble. All of which, to a chemist, means just as much as the following does to an entomologist: "*Melanoplus duodecimpunctata*, also known as the grasshopper, is an eight-legged lepidopterous insect that lays its eggs in running water."

At the Atlantic City meeting of the American Association of Economic Entomologists, held in December 1936, the writer noticed that entomologists used the terms "sulfated" and "sulfonated" indiscriminately in speaking of some of the newer wetting agents. Moreover, in writing on wetting agents entomologists confuse these terms. For example, on page 1176 of the Journal for December 1936 the statement is made

that a "sulfonated higher alcohol" used as a contact spray was effective in controlling the boxelder bug. The writer of this note means a "sulfated higher alcohol." "Sulfonated higher alcohol" is another insect that breathes through its nose and apparently is a cross between a doodle bug and a termite.

Sulfated and sulfonated compounds not the same.—The difference between sulfated and sulfonated compounds is that the former are esters of sulfuric acid, whereas the latter contain the radical $-SO_2OH$. In the sulfated compounds the sulfur atom is linked to carbon through the oxygen atom; in sulfonated compounds the sulfur is joined directly to carbon. Sulfated alcohols, more correctly called alkyl sulfates if the alcohol belongs to the series $C_nH_{2n+2}O$ or alkenyl sulfates if the alcohol belongs to the series $C_nH_{2n}O$, are made by treating the alcohols with sulfuric acid, chlorosulfonic acid, or sulfur trioxide under carefully controlled conditions. (See U. S. Patent 2,062,842 of December 1, 1936.) Temperature control is especially important. At moderate temperatures (up to 50° C) sulfates are formed; at higher temperatures some sulfonate may be formed. Alcohols may react with sulfuric acid to form other compounds also, such as ethers and unsaturated hydrocarbons.

It is unfortunate that the chemical literature contains many confusing statements concerning sulfonated products. This is because the nature of the products formed by the action of sulfuric acid on a fatty oil, on crude petroleum, or other substances has not been understood. These old names persist to the great confusion of everyone. For example, Turkey-red oil is called "sulfonated" castor oil. As a matter of fact, Turkey-red oil contains the ammonium salt of ricinoleic sulfuric acid ester and is therefore a sulfated rather than a sulfonated product. Chemists are familiar with instances where the older, incorrect chemical names persist, especially in trade usage and even in patent literature. One of the most familiar examples is the use of the term "sodium hyposulfite" or "hypo" for sodium thiosulfate. Entomologists will do well to use the names for chemicals used by the American Chemical Society in the index of Chemical Abstracts.

There are now used as detergents and as wetting agents, especially in the textile industry, two types of aliphatic compounds, (1) sulfated alcohols or alkyl sulfates and (2) alkyl sulfonates or *Igepons*.

The sulfated alcohols used are the sulfuric acid esters of the straight-chain fatty alcohols ranging from eight to 18 carbons and possibly higher. To simplify the nomenclature, the salts of these high-molecular-weight sulfated alcohols are referred to as hymolal salts. The sodium hymolal salts, for example, are white solids and rather more crystalline than soap. These salts are not affected by the hardness in water, and aqueous solutions are stable in alkalies and retain their soaplike qualities. The salts of three sulfated alcohols are now made, but in each case the alcohol is a mixture covering a given range, *e.g.*, from C_{10} to C_{14} or C_{16} to C_{18} in the saturated series, and from C_{16} to C_{18} in the unsaturated series. The principal components of these salts are sodium lauryl sulfate, sodium octadecyl sulfate, and sodium oleyl sulfate, respectively. The mixture containing sodium lauryl sulfate is marketed in the textile trade under the name *Gardinol WA*, in the nontextile bulk trade as *Orvus*, and

in the retail trade as a spray-dried granulated product under the name *Dreft*.

The *Igepons* are alkyl sulfonates. *Igepon A* is formed by the action of isethionic acid (hydroxyethanesulfonic acid, $HOCH_2CH_2SO_3H$) or its salt upon oleic acid or its derivatives. The formula of *Igepon A* is $CH_3(CH_2)_7CH=CH(CH_2)_7COOCH_2CH_2SO_3Na$. *Igepon A* is a good detergent, is neutral in its reaction, is resistant to hard water, and can be used in acids of moderate concentration, although it is decomposed if held long on the acid side. It cannot be used with alkalies, however, as they split the molecule at the carboxyl group with the formation of soap. To correct this difficulty *Igepon T* was developed, which stands up better in both alkaline and acid solutions but otherwise is similar to *Igepon A*. The formula of *Igepon T* is $CH_3(CH_2)_7CH=CH(CH_2)_7CONHCH_2CH_2SO_3Na$.

A third class of wetting agents consists of sulfonated aromatic compounds such as benzene, naphthalene and biphenyl. Products familiar to the entomologist that belong to this class are *Vatsol* and *Aresket*.

Composition of wetting agents.—All three classes of wetting agents are useful detergents and also have other uses, but on account of differences in their physical and chemical properties it is highly desirable that entomologists do not confuse them. According to the 1935–1936 Yearbook of the American Association of Textile Chemists and Colorists (page 386), the chemical composition of certain wetting agents is as follows:

Alkanols B, HG and SA	Sodium alkylnaphthalenesulfonate
Brilliant Avirol L 142 Pst	Sulfated technical stearyl alcohol
Brilliant Avirol L 144	Sulfated technical oleyl alcohol
Brilliant Avirol L 168 Pst.	Sulfated and free technical stearyl alcohol
Duponol LS flakes or paste	Sodium oleyl sulfate
Duponol ME dry	Sodium lauryl sulfate
Duponol WA flakes or paste	Sodium sulfate of technical lauryl alcohol
Gardinol LS flakes or paste	Sodium sulfate of technical oleyl alcohol
Gardinol WA flakes or paste	Sodium sulfate of technical lauryl alcohol
Invadine N	Sodium alkylnaphthalenesulfonate
Nekal A	Sodium alkylnaphthalenesulfonate
Nekal BX	Sodium alkylnaphthalenesulfonate
Neopen SS	Sodium abietenesulfonate
Permeko	Sodium alkylnaphthalenesulfonate

New materials require care in describing.—If the entomologist does not know the difference between a diphenol and diphenyl or between sulfated and sulfonated, as evidenced by some papers, he should refrain from writing about these materials. Twenty-five years ago only a very few materials were used as insecticides and fungicides, and their chemistry was relatively simple. Within recent years a host of new products have been promoted for pest control or for use as wetters, spreaders, emulsifiers, stickers or what not in conjunction with insecticides and fungicides. Most of these are organic compounds, and their chemistry is complicated in comparison with that of lead arsenate, lime sulfur solution, and the other products of a former generation. If entomologists

are to work intelligently with, and to speak intelligently and write intelligently (also intelligibly!) about, the newer products such as rotenone, thiocyanates, phenothiazine, tetramethyl thiuramdisulfide, etc., they should brush up on their chemistry or consult the chemist of the experiment station where they are located. If the entomologist confuses benzene with benzine, dehydro with dihydro, phenol with phenyl, fluorene with fluorine, rotenone with rotenonone, pyrethrin with pyrethrum, sulfated with sulfonated, etc., etc., what will he do if products such as piperidinium tetrathiocyanatodiamminochromium (recently patented as a codling moth poison) become common?

Types of common errors.—Especially to be deprecated is the practice adopted by entomologists of referring to some of the longer named organic insecticides by initials. Thus, paradichlorobenzene is called "PDB," and dinitroorthocyclohexylphenol is termed "DNOCHP." Why not refer to the Latin names of insects by initials? These are more difficult than chemical names. If the present practice is extended, we may read something like the following:

> A ton of PDB was purchased at the price of 16¢ a lb. f.o.b. and shipped C.O.D. via the C.N.O. & T.P.R.R. This was applied to the peach trees in the usual way for the control of the A.E.O. Later L.S.S. was applied for the control of A.S.L.T. DNOCHP was tried against the eggs of M.P.C., but on account of using an overdose it killed the trees P.D.Q.

Much confusion results from the entomologists mistaking a generic chemical name for a specific one. The term "manganese arsenate" covers 17 different manganous and manganic salts of ortho, meta and pyroarsenic acids, which are dissimilar in their physical, chemical and insecticidal properties. Moreover, the commercial arsenical often referred to as "manganese arsenate" is a mixture of arsenates of manganese and also arsenates of calcium. The term "alkyl thiocyanate" applies to a number of compounds that are quite unlike in their characteristics. The term "organic thiocyanate" is even broader. The compilation of organic sulfur compounds used as insecticides, by Roark & Busbey, listed 78 compounds containing the thiocyano (—SCN) radical. These range in toxicity to insects from methyl thiocyanate, which rivals hydrocyanic acid in toxicity to the California red scale, to compounds that are practically inert. To speak of tests with "alkyl thiocyanate plus sulfated alcohol," as is done in a recent state experiment station bulletin, is equivalent to saying that "the blowfly was found on the mammal."

On the other hand, the entomologist often applies a specific name to a generic material. For example, he refers to a dust made by mixing powdered derris root with an inert diluent as a "rotenone dust." Undoubtedly, rotenone is a constituent of the derris used, but other constituents are present, some of which are much more toxic to mammals when taken by mouth than is rotenone and which also have insecticidal action. It is important to differentiate between a rotenone dust, consisting of 1 per cent rotenone and 99 per cent talc, and a derris dust, consisting of 20 per cent derris and 80 per cent talc, which has a rotenone content of 1 per cent.

License for exterminators and sauce for the gander.—Entomologists in certain states are advocating the licensing of fumigators, extermina-

tors, and those who for hire apply horticultural sprays. According to plans, before the applicant is granted a license he is to be examined as to his knowledge of insects and materials for their control. The entomologists are looking forward with glee to finding an exterminator or termite proofer who mistakes an Argentine ant or even a silverfish for a termite. Moreover, if in answer to the question "What insecticide should be used to control San Jose scale?" the luckless applicant replies "arsenate of lead," he is to be thrown out the door to the accompaniment of the Bronx cheer.

No exterminator of any experience, however, is likely to accept the recommendation of the government entomologist (not the U. S. Government) who in 1936 published the following directions for the control of roaches:

> Put in a saucer a mixture of Plaster of Paris, 1 part, and flour 3 parts. Place bridges made of pieces of wood or paper over the layer of powder and put the baited saucer where roaches abound. In another flat plate nearby, put pure water and some pieces of wood to act as bridges. The roaches after eating the powder become thirsty and drink water. This makes the Plaster of Paris set and clog the intestines.

The writer believes that fumigators, etc., should be examined before they are licensed, but he also wishes to suggest that entomologists be examined before they are allowed to test, or at least talk or write about, the newer insecticides. An examination of this sort may reveal a complex or even a psychosis of which the entomologist is unaware. Two of the most prevalent fixed ideas of entomologists are that hydrated lime must be used with all dusts and that soap (the more strongly alkaline the better) must be used in all sprays. If the entomologist, in reply to the question "How would you apply derris powder as a dust?" answers (as he surely will) "In combination (meaning in admixture) with alkyl thiocyanate as a synergistic agent plus 'sulfonated' alcohol as a wetting agent plus hydrated lime . . . ," the only proper punishment to fit the crime will be to discharge both barrels of a double-barreled shotgun aimed directly at his *Gluteus maximus*. If this were done, we would not have entomologists writing articles expressing surprise that barium fluosilicate reacts with nicotine sulfate or mixing hydrated lime with sodium fluosilicate or derris, pyrethrum extract with alkalies, phenothiazine with Bordeaux mixture, etc.

The "termite proofer" who mistakes silverfish for termites and injects some orthodichlorobenzene into the beams of a house causes no loss to anyone except the owner of the house. At any rate, he does not write a paper referring to the silverfish as a termite and get it published in a scientific journal. Moreover, the termite "expert" may be an automobile mechanic out of a job and cannot be expected to have a scientific and technical education. The entomologist, on the other hand, has had at least a course in freshman chemistry and has access to chemical libraries and to chemists. Alas, this does not deter him from making the most egregious blunders in chemistry! At the Atlantic City meeting of the Association a prominent entomologist declared in a solemn and dogmatic manner that derris dust should be applied to pea vines only when they are wet, so that the active principles can be dissolved out by the water

and hence act on the pea aphids. The solubility of rotenone in water is about one in one million. The solubility of deguelin and the other constituents of derris in water is also very low. It is true that when derris powder is steeped in water a long time or extracted in a Soxhlet with boiling water, the water becomes toxic to aphids and other insects. This is due to rotenone and other constituents in suspension in the water, not in solution, as passage through an unglazed porcelain filter readily shows.

Misinformation concerning the organic insecticides delays the progress of insect control. It is hoped that entomologists will be careful to check their information on these products. Otherwise we shall be treated to even more fantastic descriptions of the chemical equivalents of "insects that breathe through the nose."—4-12-37.

Common Names of Insects

Approved for General Use by the American Association of Economic Entomologists

The Committee on Common Names, in conformity with instructions received at the forty-eighth annual meeting of the American Association of Economic Entomologists, has brought together the common names so far approved by the Association and has added thereto the names which received the necessary vote for adoption this year.

This list supersedes and voids all previous lists, and the American Association of Economic Entomologists strongly urges that its members and such others that are in sympathy with its policy use every effort to have these names used in all publications emanating from the institutions with which they are connected.

Insects Listed by Common Names

achemon sphinx ..... *Pholus achemon* (Drury)
Alaska spruce beetle ..... *Dendroctonus borealis* Hopk.
alder bark beetle ..... *Alniphagus aspericollis* (Lec.)
alder flea beetle ..... *Altica bimarginata* Say
alfalfa caterpillar ..... *Eurymus eurytheme* (Bvd.)
alfalfa gall midge ..... *Asphondylia websteri* Felt
alfalfa looper ..... *Autographa californica* (Speyer)
alfalfa snout beetle ..... *Brachyrhinus ligustici* (L.)
alfalfa webworm ..... *Loxostege commixtalis* (Walk.)
alfalfa weevil ..... *Hypera postica* (Gyll.)
Allegheny spruce beetle ..... *Dendroctonus punctatus* Lec.
almond moth ..... *Ephestia cautella* (Walk.)
American cockroach ..... *Periplaneta americana* (L.)
American dagger moth ..... *Acronicta americana* (Harr.)
American dog tick ..... *Dermacentor variabilis* (Say)
American grasshopper ..... *Schistocerca americana* (Drury)
angoumois grain moth ..... *Sitotroga cerealella* (Oliv.)
angular-winged katydid ..... *Microcentrum retinerve* (Burm.)
apple and thorn skeletonizer ..... *Hemerophila pariana* (Clerck)
apple aphid ..... *Aphis pomi* Deg.
apple bark miner ..... *Marmara elotella* Busck

apple curculio	*Tachypterellus quadrigibbus* (Say)
apple flea weevil	*Orchestes pallicornis* Say
apple fruit miner	*Marmara pomonella* Busck
apple fruit moth	*Argyresthia conjugella* Zell.
apple grain aphid	*Rhopalosiphum prunifoliae* (Fitch)
apple leafhopper	*Empoasca maligna* (Walsh)
apple leaf skeletonizer	*Psorosina hammondi* (Riley)
apple leaf trumpet miner	*Tischeria malifoliella* Clem.
apple maggot	*Rhagoletis pomonella* (Walsh)
apple redbug	*Lygidea mendax* Reut.
apple seed chalcid	*Callimome druparum* (Boh.)
apple sucker	*Psyllia mali* (Schmidt)
apple twig beetle	*Hypothenemus hispidulus* (Lec.)
apple twig borer	*Schistoceros hamatus* (F.)
arborvitae leaf miner	*Argyresthia thuiella* (Pack.)
Argentine ant	*Iridomyrmex humilis* Mayr
argus tortoise beetle	*Chelymorpha cassidea* (F.)
Arizona cotton stainer	*Dysdercus mimulus* Hussey
Arizona pine beetle	*Dendroctonus arizonicus* Hopk.
army cutworm	*Chorizagrotis auxiliaris* (Grote)
armyworm	*Cirphis unipuncta* (Haw.)
artichoke plume moth	*Platyptilia carduidactyla* (Riley)
ash borer	*Podosesia fraxini* (Lugger)
ash-gray blister beetle	*Macrobasis unicolor* (Kby.)
Asiatic garden beetle	*Autoserica castanea* (Arrow)
Asiatic rice borer	*Chilo simplex* (Butl.)
asparagus beetle	*Crioceris asparagi* (L.)
asparagus miner	*Agromyza simplex* Loew
Australian cockroach	*Periplaneta australasiae* (F.)
Australian pine borer	*Chrysobothris tranquebarica* (Gmel.)
avocado red mite	*Paratetranychus yothersi* McG.
avocado whitefly	*Trialeurodes floridensis* (Quaint.)
bagworm	*Thyridopteryx ephemeraeformis* (Haw.)
bald-faced hornet	*Vespula maculata* (L.)
balsam fir sawyer	*Monochamus marmorator* Kby.
balsam twig aphid	*Mindarus abietinus* Koch
banana root borer	*Cosmopolites sordidus* (Germ.)
banded cucumber beetle	*Diabrotica balteata* Lec.
banded woolly bear	*Isia isabella* (S. & A.)
barnacle scale	*Ceroplastes cirripediformis* Comst.
bean aphid	*Aphis rumicis* L.
bean leaf beetle	*Cerotoma trifurcata* (Forst.)
bean leaf roller	*Goniurus proteus* (L.)
bean leaf skeletonizer	*Autographa egena* (Guen.)
bean weevil	*Acanthoscelides obtectus* (Say)
bean thrips	*Heliothrips fasciatus* Perg.
bedbug	*Cimex lectularius* L.
beech blight aphid	*Prociphilus imbricator* (Fitch)
beech scale	*Cryptococcus fagi* (Baer.)
beet armyworm	*Laphygma exigua* (Hbn.)
beet leaf beetle	*Monoxia puncticollis* (Say)
beet leafhopper	*Eutettix tenellus* (Bak.)
beet webworm	*Loxostege sticticalis* (L.)
bertha armyworm	*Barathra configurata* (Walk.)
birch skeletonizer	*Bucculatrix canadensisella* Chamb.
bird tick	*Haemaphysalis cinnabarina* Koch
black army cutworm	*Agrotis fennica* Tausch.
black blister beetle	*Epicauta pennsylvanica* (Deg.)
black carpenter ant	*Camponotus herculeanus pennsylvanicus* (Deg.)
black carpet beetle	*Attagenus piceus* (Oliv.)
black cherry aphid	*Myzus cerasi* (F.)

black cherry fruitfly	*Rhagoletis fausta* O. S.
black citrus aphid	*Toxoptera aurantiae* Boyer
black cutworm	*Agrotis ypsilon* (Rott.)
black elm bark weevil	*Magdalis barbita* (Say)
black grain stem sawfly	*Trachelus tabidus* (F.)
black-headed budworm	*Peronea variana* (Fern.)
black-headed fireworm	*Rhopobota naevana* (Hbn.)
Black Hills beetle	*Dendroctonus ponderosae* Hopk.
black-horned tree cricket	*Oecanthus nigrocornis* Walk.
black horsefly	*Tabanus atratus* F.
black ladybeetle	*Rhizobius ventralis* (Er.)
black-legged tick	*Ixodes ricinus scapularis* Say
black-legged tortoise beetle	*Jonthonota nigripes* (Oliv.)
black peach aphid	*Anuraphis persicae-niger* (Smith)
black pecan aphid	*Melanocallis caryaefoliae* (Davis)
black scale	*Saissetia oleae* (Bern.)
black swallowtail	*Papilio polyxenes* F.
black thread scale	*Ischnaspis longirostris* (Sign.)
black turpentine beetle	*Dendroctonus terebrans* (Oliv.)
black vine weevil	*Brachyrhinus sulcatus* (F.)
black widow spider	*Latrodectus mactans* F.
bloodsucking conenose	*Triatoma sanguisuga* (Lec.)
blueberry maggot	*Rhagoletis pomonella* (Walsh)
bluebottle flies	*Calliphora* spp.
body louse	*Pediculus humanus corporis* Deg.
boll weevil	*Anthonomus grandis* Boh.
bollworm	*Heliothis obsoleta* (F.)
booklouse	*Troctes divinatorius* (Müll.)
boxelder aphid	*Periphyllus negundinis* (Thos.)
boxelder bug	*Leptocoris trivittatus* (Say)
boxelder leaf roller	*Gracilaria negundella* Chamb.
boxelder twig borer	*Proteoteras willingana* (Kearf.)
boxwood leaf miner	*Monarthropalpus buxi* Laboulb.
boxwood psyllid	*Psyllia buxi* (L.)
bristly cutworm	*Polia renigera* (Steph.)
bristly rose slug	*Cladius isomerus* Nort.
broadbean weevil	*Bruchus rufimanus* Boh.
broad mite	*Tarsonemus latus* Banks
broad-necked root borer	*Prionus laticollis* (Drury)
bronzed cutworm	*Nephelodes emmedonia* (Cram.)
bronzed birch borer	*Agrilus anxius* Gory
brown chicken louse	*Goniodes dissimilis* Nitz.
brown dog tick	*Rhipicephalus sanguinius* Latr.
brown salt-marsh mosquito	*Aedes cantator* (Coq.)
brown spider beetle	*Ptinus brunneus* Dufts.
brown winter tick	*Dermacentor nigrolineatus* (Pack.)
brown-tail moth	*Nygmia phaeorrhoea* (Donov.)
Bruce's spanworm	*Rachela bruccata* (Hulst)
buck moth	*Hemileuca maia* (Drury)
buffalo treehopper	*Ceresa bubalus* (F.)
bulb mite	*Rhizoglyphus hyacinthi* Bdv.
bulb scale mite	*Tarsonemus approximatus narcissi* Ewing
bumble flower beetle	*Euphoria inda* (L.)
bumelia fruitfly	*Anastrepha pallens* Coq.
cabbage aphid	*Brevicoryne brassicae* (L.)
cabbage curculio	*Ceutorhynchus rapae* Gyll.
cabbage looper	*Autographa brassicae* (Riley)
cabbage maggot	*Hylemyia brassicae* (Bouché)
cabbage seedstalk curculio	*Ceutorhynchus quadrideus* (Panz.)
cabbage webworm	*Hellula undalis* (F.)
cactus scale	*Diaspis echinocacti* (Bouché)

cadelle ..... *Tenebroides mauritanicus* (L.)
calico scale ..... *Lecanium cerasorum* Ckll.
California harvester ant ..... *Pogonomyrmex californicus* (Buckl.)
California oak worm ..... *Phryganidia californica* Pack.
California pear slug ..... *Micronematus californicus* (Marlatt)
California prionus ..... *Prionus californicus* Mots.
California red scale ..... *Chrysomphalus aurantii* (Mask.)
California salt-marsh mosquito ..... *Aedes squamiger* (Coq.)
California tent caterpillar ..... *Malacosoma californica* (Pack.)
camphor scale ..... *Pseudaonidea duplex* (Ckll.)
camphor thrips ..... *Cryptothrips floridensis* Watson
Caribbean pod borer ..... *Fundella cistipennis* (Dyar)
Carolina grasshopper ..... *Dissosteira carolina* (L.)
Carolina mantis ..... *Stagmomantis carolina* (Johan.)
carpenter bee ..... *Xylocopa virginica* (Drury)
carpenter worm ..... *Prionoxystus robiniae* (Peck)
carpet beetle ..... *Anthrenus scrophulariae* (L.)
carpet moth ..... *Trichophaga tapetzella* (L.)
carrot beetle ..... *Ligyrus gibbosus* (Deg.)
carrot rust fly ..... *Psila rosae* (F.)
carrot weevil ..... *Listronotus latiusculus* (Boh.)
casebearing clothes moth ..... *Tinea pellionella* L.
castor-bean tick ..... *Ixodes ricinus* (L.)
catalpa midge ..... *Itonida catalpae* Comst.
catalpa sphinx ..... *Ceratomia catalpae* (Bdv.)
cat flea ..... *Ctenocephalides felix* (Bouché)
cat follicle mite ..... *Demodex cati* Megn.
cat louse ..... *Felicola subrostrata* (Nitz.)
cattle biting-louse ..... *Bovicola bovis* (Nitz.)
cattle follicle mite ..... *Demodex bovis* Stiles
cattle tick ..... *Boophilus annulatus* (Say)
cecropia moth ..... *Platysamia cecropia* (L.)
cedar tree borer ..... *Anocomis lignea* (F.)
celery looper ..... *Autographa falcifera* (Kby.)
celery worm ..... *Papilio polyxenes* F.
chaff scale ..... *Parlatoria pergandii* Comst.
chain-spotted geometer ..... *Cingilia catenaria* (Drury)
changa ..... *Scapteriscus vicinus* Scudd.
charcoal beetle ..... *Melanophila consputa* Lec.
cheese skipper ..... *Piophila casei* L.
cherry casebearer ..... *Coleophora pruniella* Clem.
cherry fruitfly ..... *Rhagoletis cingulata* (Loew)
cherry fruitworm ..... *Grapholitha packardi* Zell.
cherry leaf beetle ..... *Galerucella cavicollis* (Lec.)
cherry maggot ..... *Rhagoletis cingulata* (Loew)
cherry scale ..... *Aspidiotus forbesi* Johns.
chestnut timber worm ..... *Melittomma sericeum* Harr.
chestnut weevil ..... *Curculio rectus* (Say)
chicken body louse ..... *Eomenacanthus stramineus* (Nitz.)
chicken head louse ..... *Lipeurus heterographus* Nitz.
chicken mite ..... *Dermanyssus gallinae* (Deg.)
chigger ..... *Trombicula irritans* (Riley)
chigoe ..... *Tunga penetrans* (L.)
chinch bug ..... *Blissus leucopterus* (Say)
Chinese mantis ..... *Tenodera sinensis* Sauss.
chrysanthemum aphid ..... *Macrosiphoniella sanborni* (Gill.)
chrysanthemum gall midge ..... *Diathronomyia hypogaea* Loew
chrysanthemum leaf miner ..... *Phytomyza chrysanthemi* (Kowarz)
cicadas ..... Cicadidae
cigar casebearer ..... *Coleophora fletcherella* Fern.
cigarette beetle ..... *Lasioderma serricorne* (F.)
citricola scale ..... *Coccus pseudomagnoliarum* (Kuw.)

citrophilus mealybug ..... *Pseudococcus gahani* Green
citrus blackfly ..... *Aleurocanthus woglumi* Ashby
citrus mealybug ..... *Pseudococcus citri* (Risso)
citrus red mite ..... *Paratetranychus citri* McG.
citrus rust mite ..... *Phyllocoptes oleivorus* Ashm.
citrus thrips ..... *Scirtothrips citri* (Moult.)
citrus whitefly ..... *Dialeurodes citri* Ashm.
clear-winged grasshopper ..... *Camnula pellucida* (Scudd.)
clouded sulphur ..... *Eurymus philodice* (Godt.)
cloudy-winged whitefly ..... *Dialeurodes citrifolii* (Morg.)
clover aphid ..... *Anuraphis bakeri* (Cowen)
clover cutworm ..... *Scotogramma trifolii* (Rott.)
clover hay worm ..... *Hypsopygia costalis* (F.)
clover head caterpillar ..... *Grapholitha interstinctana* (Clem.)
clover head weevil ..... *Tychius griseus* Schaeffer
clover leaf midge ..... *Dasyneura trifolii* (Loew)
clover leaf weevil ..... *Hypera punctata* (F.)
clover mite ..... *Bryobia praetiosa* Koch
clover root borer ..... *Hylastinus obscurus* (Marsham)
clover root curculio ..... *Sitona hispidula* (F.)
clover seed chalcid ..... *Bruchophagus gibbus* (Boh.)
clover seed midge ..... *Dasyneura leguminicola* (Lint.)
clover stem borer ..... *Languria mozardi* Latr.
cluster fly ..... *Pollenia rudis* (F.)
coconut leaf roller ..... *Omiodes blackburni* (Butl.)
coconut mealybug ..... *Pseudococcus nipae* (Mask.)
codling moth ..... *Carpocapsa pomonella* L.
coffee-bean weevil ..... *Araecerus fasciculatus* (Deg.)
Colorado pine beetle ..... *Dendroctonus approximatus* Dietz
Colorado potato beetle ..... *Leptinotarsa decemlineata* (Say)
Columbia Basin wireworm ..... *Limonius subauratus* Lec.
Columbian timber beetle ..... *Corthylus columbianus* Hopk.
columbine borer ..... *Papaipema purpurifascia* (G. & R.)
columbine leaf miner ..... *Phytomyza aquilegiae* (Hardy)
common cattle grub ..... *Hypoderma lineatum* (DeVill.)
common malarial mosquito ..... *Anopheles quadrimaculatus* Say
common red spider ..... *Tetranychus telarius* (L.)
confused flour beetle ..... *Tribolium confusum* Duv.
convergent ladybeetle ..... *Hippodamia convergens* Guer.
corn billbugs ..... *Calendra* spp.
corn blotch leaf miner ..... *Agromyza parvicornis* Loew
corn ear worm ..... *Heliothis obsoleta* (F.)
corn flea beetle ..... *Chaetocnema pulicaria* Melsh.
corn leaf aphid ..... *Aphis maidis* Fitch
corn root aphid ..... *Anuraphis maidi-radicis* (Forbes)
corn root webworm ..... *Crambus caliginosellus* Clem.
corn rootworm ..... *Diabrotica longicornis* (Say)
corn sap beetle ..... *Carpophilus dimidiatus* (F.)
corn silk beetle ..... *Luperodes brunneus* Crotch
cornfield ant ..... *Lasius niger americanus* Emery
cotton aphid ..... *Aphis gossypii* Glov.
cotton blister mite ..... *Eriophyes gossypii* Banks
cotton flea hopper ..... *Psallus seriatus* (Reut.)
cotton lacebug ..... *Corythucha gossypii* (F.)
cotton leaf perforator ..... *Bucculatrix thurberiella* Busck
cotton leaf worm ..... *Alabama argillacea* (Hbn.)
cotton square borer ..... *Strymon melinus* (Hbn.)
cotton stainer ..... *Dysdercus suturellus* (H. S.)
cottonwood leaf beetle ..... *Chrysomela scripta* F.
cottony-cushion scale ..... *Icerya purchasi* Mask.
cottony maple scale ..... *Pulvinaria vitis* (L.)
cottony peach scale ..... *Pulvinaria amygdali* Ckll.

coulee cricket ..... *Peranabrus scabricollis* (Thos.)
cowpea aphid ..... *Aphis medicaginis* Koch
cowpea curculio ..... *Chalcodermus aeneus* Boh.
cowpea weevil ..... *Callosobruchus maculatus* (F.)
crab hole mosquito ..... *Deinocerites cancer* Theob.
crab louse ..... *Phthirus pubis* (L.)
cranberry fruitworm ..... *Mineola vaccinii* (Riley)
cranberry girdler ..... *Crambus hortuellus* (Hbn.)
cranberry rootworm ..... *Rhabdopterus picipes* (Oliv.)
cranberry spanworm ..... *Cleora pampinaria* (Guen.)
cranberry weevil ..... *Anthonomus musculus* Say
crapemyrtle aphid ..... *Myzocallis kahawaluokalani* Kirk.
crazy ant ..... *Prenolepis longicornis* (Latr.)
cross-striped cabbage worm ..... *Evergestis rimosalis* (Guen.)
Cuban cockroach ..... *Panchlora cubensis* Sauss.
Cuban laurel thrips ..... *Gynaikothrips uzeli* (Zimm.)
curled rose sawfly ..... *Emphytus cinctipes* Nort.
currant aphid ..... *Capitophorus ribis* (L.)
currant borer ..... *Synanthedon tipuliformis* (L.)
currant bud mite ..... *Eriophyes ribis* Nal.
currant fruitfly ..... *Epochra canadensis* Loew
currant spanworm ..... *Itame ribearia* (Fitch)
currant stem girdler ..... *Janus integer* (Nort.)
cyclamen mite ..... *Tarsonemus pallidus* Banks

dark mealworm ..... *Tenebrio obscurus* F.
dark-sided cutworm ..... *Euxoa messoria* (Harr.)
date bug ..... *Asarcopus palmarum* Horv.
date mite ..... *Paratetranychus heteronychus* Ewing
deer flies ..... *Chrysops* spp.
deodar weevil ..... *Pissodes nemorensis* Germ.
depluming mite ..... *Cnemidocoptes gallinae* Raill.
desert corn flea beetle ..... *Chaetocnema ectypa* Horn
devastating grasshopper ..... *Melanoplus devastator* Scudd.
diamondback moth ..... *Plutella maculipennis* (Curt.)
dictyospermum scale ..... *Chrysomphalus dictospermi* (Morg.)
differential grasshopper ..... *Melanoplus differentialis* (Thos.)
dingy cutworm ..... *Feltia subgothica* (Haw.)
dobson fly ..... *Corydalis cornuta* (L.)
dock sawfly ..... *Ametastegia glabrata* (Fall.)
dog flea ..... *Ctenocephalides canis* (Curt.)
dog follicle mite ..... *Demodex canis* Leydig
Douglas fir beetle ..... *Dendroctonus pseudotsugae* Hopk.
Douglas fir engraver ..... *Scolytus unispinosus* Lec.
Douglas fir tussock moth ..... *Hemerocampa pseudotsugata* McD.
dried fruit beetle ..... *Carpophilus hemipterus* (L.)
dried fruit mite ..... *Carpoglyphus passularum* Her.
dried fruit moth ..... *Vitula serratilinecella* Rag.
drug store weevil ..... *Stegobium paniceum* (L.)
dry-land wireworm ..... *Ludius inflatus* (Say)

ear tick ..... *Ornithodoros megnini* Duges
eastern field wireworm ..... *Limonius ectypus* (Say)
eastern larch beetle ..... *Dendroctonus simplex* Lec.
eastern lubber grasshopper ..... *Romalea microptera* (Beauv.)
eastern spruce beetle ..... *Dendroctonus piceaperda* Hopk.
eastern tent caterpillar ..... *Malacosoma americana* (F.)
eggplant flea beetle ..... *Epitrix fuscula* Crotch
eggplant lacebug ..... *Gargaphia solani* Heid.
eggplant leaf miner ..... *Gnorimoschema glochinella* (Zell.)
eight-spotted forester ..... *Alypia octomaculata* (F.)
elm borer ..... *Saperda tridentata* Oliv.

elm casebearer	*Coleophora limosipennella* Dup.
elm cockscomb gall	*Colopha ulmicola* (Fitch)
elm leaf beetle	*Galerucella xanthomelaena* (Schr.)
elm leaf miner	*Kaliosysphinga ulmi* (Sund.)
elm sawfly	*Cimbex americana* Leach
elm scurfy scale	*Chionaspis americana* Johns.
elm spanworm	*Ennomos subsignarius* (Hbn.)
Engelmann spruce beetle	*Dendroctonus engelmanni* Hopk.
Engelmann spruce weevil	*Pissodes engelmanni* Hopk.
English grain aphid	*Macrosiphum granarium* (Kby.)
ermine moth	*Hyponomeuta malinellus* Zell.
euonymus scale	*Chionaspis euonymi* Comst.
European alder leaf miner	*Fenusa dorhnii* (Tischbein)
European chicken flea	*Ceratophyllus gallinae* Schr.
European corn borer	*Pyrausta nubilalis* (Hbn.)
European earwig	*Forficula auricularia* L.
European elm scale	*Gossyparia spuria* (Mod.)
European fruit lecanium	*Lecanium corni* Bouché
European fruit scale	*Aspidiotus ostreaeformis* Curt.
European grain moth	*Tinea granella* L.
European peach scale	*Lecanium persicae* (F.)
European pine shoot moth	*Rhyacionia buoliana* (Schiff.)
European red mite	*Paratetranychus pilosus* (C. & F.)
European spruce beetle	*Dendroctonus micans* Kug.
European spruce sawfly	*Diprion polytomum* (Htg.)
European wheat stem sawfly	*Cephus pygmaeus* (L.)
eye gnats	*Hippelates* spp.
eye-spotted budmoth	*Spilonota ocellana* (D. & S.)
eyed click beetle	*Alaus oculatus* (L.)
fall armyworm	*Laphygma frugiperda* (S. & A.)
fall cankerworm	*Alsophila pometaria* (Harr.)
fall webworm	*Hyphantria cunea* (Drury)
false chinch bug	*Nysius ericae* (Schill.)
false potato beetle	*Leptinotarsa juncta* (Germ.)
false stablefly	*Muscina stabulans* Fall.
fern scale	*Hemichionaspis aspidistrae* (Sign.)
field cricket	*Gryllus assimilis* F.
fiery hunter	*Calosoma calidum* (F.)
fig mite	*Eriophyes fici* Essig
fig scale	*Lepidosaphes ficus* (Sign.)
fir engraver	*Scolytus ventralis* Lec.
fir flatheaded borer	*Melanophila fulvoguttata drummondi* (Kby.)
fire ant	*Solenopsis geminata* (F.)
firebrat	*Thermobia domestica* Pack.
flat grain beetle	*Laemophloeus minutus* Oliv.
flatheaded apple tree borer	*Chrysobothris femorata* (Oliv.)
flesh flies	*Sarcophaga* spp.
floodwater mosquito	*Aedes hirsuteron* (Theob.)
Florida harvester ant	*Pogonomyrmex badius* (Latr.)
Florida red scale	*Chrysomphalus aonidium* (L.)
Florida wax scale	*Ceroplastes floridensis* Comst.
flour beetles	*Tribolium* spp.
flower thrips	*Frankliniella tritici* (Fitch)
fluff louse	*Gonicotes hologaster* Nitz.
forage looper	*Caenurgia erechtea* (Cram.)
forest tent caterpillar	*Malacosoma disstria* Hbn.
fork-tailed bush katydid	*Scudderia furcata* Brunner
four-lined plant bug	*Poecilocapsus lineatus* (F.)
four-spotted tree cricket	*Oecanthus nigricornis quadripunctatus* Beut.
fowl tick	*Argas miniatus* Koch
frit fly	*Oscinella frit* L.

fruit tree leaf roller ..... *Cacoecia argyrospila* (Walk.)
Fuller's rose beetle ..... *Pantomorus godmani* (Crotch)

gall-making maple borer ..... *Xylothechus aceris* Fisher
garden centipede ..... *Scutigerella immaculata* (Newp.)
garden flea hopper ..... *Halticus citri* (Ashm.)
garden springtail ..... *Bourletiella hortensis* (Fitch)
garden webworm ..... *Loxostege similalis* (Guen.)
German cockroach ..... *Blattella germanica* (L.)
giant hornet ..... *Vespa crabro* L.
giant stag beetle ..... *Lucanus elaphus* F.
giant water bug ..... *Lethocerus americanus* (Leidy)
gladiolus thrips ..... *Taeniothrips simplex* Morison
glassy cutworm ..... *Sidemia devastatrix* (Brace)
globose scale ..... *Lecanium prunastri* (Boyer)
gloomy scale ..... *Chrysomphalus tenebricosus* (Comst.)
Glover's scale ..... *Lepidosaphes gloverii* (Pack.)
goat follicle mite ..... *Demodex caprae* Raill.
goldenglow aphid ..... *Macrosiphum rudbeckiae* (Fitch)
golden spider beetle ..... *Niptus hololeucus* Fald.
golden tortoise beetle ..... *Metriona bicolor* (F.)
gooseberry fruitworm ..... *Zophodia grossulariae* (Riley)
gooseberry witch-broom aphid ..... *Kakimia houghtonensis* (Troop)
granary weevil ..... *Sitophilus granarius* (L.)
granulate cutworm ..... *Feltia annexa* (Treit.)
grape berry moth ..... *Polychrosis viteana* (Clem.)
grape blossom midge ..... *Contarinia johnsoni* Sling.
grape cane gall maker ..... *Ampeloglypter sesostris* (Lec.)
grape colaspis ..... *Colaspis brunnea* (F.)
grape curculio ..... *Craponius inaequalis* (Say)
grape flea beetle ..... *Altica chalybea* Ill.
grape leaf folder ..... *Desmia funeralis* (Hbn.)
grape leafhopper ..... *Erythroneura comes* (Say)
grape leaf skeletonizer ..... *Harrisina americana* (Guer.)
grape mealybug ..... *Pseudococcus maritimus* (Ehrh.)
grape phylloxera ..... *Phylloxera vitifoliae* Fitch
grape plume moth ..... *Oxyptilus periscelidactylus* (Fitch)
grape root borer ..... *Paranthrene polistiformis* (Harr.)
grape rootworm ..... *Fidia viticida* Walsh
grape sawfly ..... *Erythraspides pygmaea* (Say)
grape scale ..... *Aspidiotus uvae* Comst.
grape seed chalcid ..... *Evoxysoma vitis* (Saund.)
grape whitefly ..... *Trialeurodes vittatus* (Quaint.)
grapevine aphid ..... *Aphis illinoisensis* Shim.
grass thrips ..... *Anaphothrips obscurus* (Müll.)
grasshopper maggot ..... *Sarcophaga kellyi* Ald.
gray blister beetle ..... *Epicauta cinerea* (Forst.)
gray-banded leaf roller ..... *Argyrotaenia mariana* (Fern.)
Great Basin wireworm ..... *Ludius pruininus noxius* (Hyslop)
greedy scale ..... *Aspidiotus camelliae* Sign.
greenbottle flies ..... *Lucilia* spp.
green budworm ..... *Olethreutes variegana* (Hbn.)
green bug ..... *Toxoptera graminum* Rond.
green clover worm ..... *Plathypena scabra* (F.)
green fruitworm ..... *Graptolitha antennata* (Walk.)
green June beetle ..... *Cotinis nitida* (L.)
green peach aphid ..... *Myzus persicae* (Sulz.)
green rose chafer ..... *Dichelonyx backi* (Kby.)
green scale ..... *Coccus viridis* (Green)
green shield scale ..... *Pulvinaria psidii* Mask.
green stinkbug ..... *Acrosternum hilaris* (Say)
green-striped maple worm ..... *Anisota rubicunda* F.

greenhouse leaf tier ... *Phyctaenia rubigalis* (Guen.)
greenhouse orthezia ... *Orthezia insignis* Dougl.
greenhouse stone cricket ... *Tachycines asynamorus* Adel.
greenhouse thrips ... *Heliothrips haemorrhoidalis* (Bouché)
greenhouse whitefly ... *Trialeurodes vaporariorum* (Westw.)
ground mealybug ... *Rhizoecus terrestris* (Newst.)
Gulf coast tick ... *Amblyomma maculatum* Koch
Gulf wireworm ... *Heteroderes laurentii* (Guer.)
gypsy moth ... *Porthetria dispar* (L.)

hackberry engraver ... *Scolytus muticus* Say
hackberry nipple gall ... *Pachypsylla celtidis-mamma* Riley
hag moth ... *Phobetron pithecium* (S. & A.)
hairy chinch bug ... *Blissus hirtus* Montd.
hairy spider beetle ... *Ptinus villiger* (Reit.)
harlequin bug ... *Murgantia histrionica* (Hahn)
Hawaiian beet webworm ... *Hymenia fascialis* (Cram.)
head louse ... *Pediculus humanus humanus* L.
hellgrammite ... *Corydalis cornuta* (L.)
hemispherical scale ... *Saissetia hemisphaerica* (Targ.)
hemlock borer ... *Melanophila fulvoguttata* (Harr.)
hemlock looper ... *Ellopia fiscellaria* Guen.
hemlock sawfly ... *Neodiprion tsugae* Midd.
hessian fly ... *Phytophaga destructor* (Say)
hickory bark beetle ... *Scolytus quadrispinosus* Say
hickory horned devil ... *Citheronia regalis* (F.)
hickory leaf roller ... *Argyrotaenia juglandana* (Fern.)
hickory shuck worm ... *Laspeyresia caryana* (Fitch)
hickory tussock moth ... *Halisidota caryae* (Harr.)
hide beetle ... *Dermestes vulpinus* F.
hog follicle mite ... *Demodex phylloides* Csokor
hog louse ... *Haematopinus suis* (L.)
holly leaf miner ... *Phytomyza ilicicola* Loew
honeybee ... *Apis mellifera* L.
hop aphid ... *Phorodon humuli* (Schr.)
hop flea beetle ... *Psylliodes punctulata* Melsh.
hop looper ... *Hypena humuli* (Harr.)
horn fly ... *Haematobia irritans* L.
horned passalus ... *Passalus cornutus* F.
horse biting-louse ... *Trichodectes equi* (L.)
horse botfly ... *Gastrophilus intestinalis* Deg.
horse follicle mite ... *Demodex equi* Raill.
horseradish flea beetle ... *Phyllotreta armoraciae* (Koch)
house centipede ... *Scutigera forceps* Raf.
house cricket ... *Gryllus domesticus* L.
housefly ... *Musca domestica* L.
Howard's scale ... *Aspidiotus howardi* Ckll.
human flea ... *Pulex irritans* L.

imbricated snout beetle ... *Epicaerus imbricatus* (Say)
imperial moth ... *Eacles imperialis* (Drury)
imported cabbage worm ... *Ascia rapae* (L.)
imported currant worm ... *Pteronidea ribesii* (Scop.)
Indian-meal moth ... *Plodia interpunctella* (Hbn.)
introduced pine sawfly ... *Diprion simile* (Htg.)
io moth ... *Automeris io* (F.)
iris borer ... *Macronoctua onusta* Grote
iris thrips ... *Bregmatothrips iridis* Watson
Italian pear scale ... *Epidiaspis piricola* (Del Guer.)
itch mite ... *Sarcoptes scabiei* Deg.
ivy aphid ... *Aphis hederae* Kltb.

Japanese beetle ... *Popillia japonica* Newm.

Jeffrey pine beetle	*Dendroctonus jeffreyi* Hopk.
Jerusalem cricket	*Stenopelmatus fuscus* Hald.
koa seed worm	*Olethreutes illepida* (Butl.)
lantana leaf bug	*Teleonemia lantanae* Dist.
lantana leaf miner	*Cremastobombycia lantanella* Busck
lantana plume moth	*Platyptilia pusillodactyla* (Walk.)
lantana seed fly	*Agromyza lantanae* Froggatt
lappet moth	*Epicnaptera americana* (Harr.)
larch casebearer	*Coleophora laricella* Hbn.
larch sawfly	*Lygaeonematus erichsonii* (Htg.)
larder beetle	*Dermestes lardarius* L.
large chestnut weevil	*Curculio proboscideus* F.
large chicken louse	*Goniocotes gigas* Tasch.
large duck louse	*Trinoton querquedulae* (L.)
large turkey louse	*Goniodes meleagridis* (L.)
larger canna leaf roller	*Calpodes ethlius* (Cram.)
larger Mexican pine beetle	*Dendroctonus parallelocollis* Chap.
larkspur leaf miner	*Phytomyza delphiniae* Frost
latrine fly	*Fannia scalaris* (F.)
lead cable borer	*Scobicia declivis* (Lec.)
leaf crumpler	*Mineola indigenella* (Zell.)
leaf-footed bug	*Leptoglossus phyllopus* (L.)
leopard moth	*Zeuzera pyrina* (L.)
lesser apple worm	*Grapholitha prunivora* (Walsh)
lesser budmoth	*Recurvaria nanella* (Hbn.)
lesser bulb fly	*Eumerus tuberculatus* Rond.
lesser clover leaf weevil	*Hypera nigrirostris* (F.)
lesser cornstalk borer	*Elasmopalpus lignosellus* (Zell.)
lesser peach borer	*Synanthedon pictipes* (G. & R.)
lilac borer	*Podosesia syringae* (Harr.)
lilac leaf miner	*Gracilaria syringella* F.
lima bean pod borer	*Etiella zinckenella* (Treit.)
lima bean vine borer	*Monoptilota pergratialis* (Hulst)
lime-tree looper	*Erannis tiliaria* (Harr.)
linden borer	*Saperda vestita* Say
lined spittle bug	*Philaenus lineatus* (L.)
little black ant	*Monomorium minimum* (Buckl.)
little carpenter worm	*Prionoxystus macmurtrei* (Guer.)
little housefly	*Fannia canicularis* L.
locust borer	*Cyllene robiniae* (Forst.)
locust leaf miner	*Chalepus dorsalis* Thunb.
lodgepole cone beetle	*Conophthorus contortae* Hopk.
lodgepole needle miner	*Recurvaria milleri* Busck
lodgepole pine beetle	*Dendroctonus murrayanae* Hopk.
lodgepole sawfly	*Neodiprion burkei* Midd.
lone star tick	*Amblyomma americanum* (L.)
long-tailed mealybug	*Pseudococcus adonidum* (L.)
lubber grasshopper	*Brachystola magna* (Gir.)
luna moth	*Tropaea luna* (L.)
magnolia scale	*Neolecanium cornuparvum* (Thro)
mango weevil	*Sternochetus mangiferae* (F.)
maple leaf cutter	*Paraclemensia acerifoliella* (Fitch)
margined blister beetle	*Epicauta marginata* (F.)
masked hunter	*Reduvius personatus* (L.)
meadow plant bug	*Miris dolabratus* (L.)
meal moth	*Pyralis farinalis* L.
mealy plum aphid	*Hyalopterus arundinis* (F.)
Mediterranean flour moth	*Ephestia kuehniella* Zell.
Mediterranean fruitfly	*Ceratitis capitata* Wied.
melon aphid	*Aphis gossypii* Glov.

melonfly ..... *Bactrocera cucurbitae* Coq.
melonworm ..... *Diaphania hyalinata* (L.)
Mexican bean beetle ..... *Epilachna varivestis* Muls.
Mexican fruitfly ..... *Anastrepha ludens* (Loew)
Mexican mealybug ..... *Phenacoccus gossypii* Towns. & Ckll.
mining scale ..... *Howardia biclavis* (Comst.)
monarch butterfly ..... *Danus menippe* (Hbn.)
Monterey pine cone beetle ..... *Conophthorus radiatae* Hopk.
Monterey pine weevil ..... *Pissodes radiatae* Hopk.
Mormon cricket ..... *Anabrus simplex* Hald.
mossy rose gall ..... *Rhodites rosae* (L.)
mottled tortoise beetle ..... *Chirida guttata* (Oliv.)
mountain pine beetle ..... *Dendroctonus monticolae* Hopk.
mourning-cloak butterfly ..... *Hamadryas antiova* (L.)
mulberry whitefly ..... *Tetraleurodes mori* Quaint.

narcissus bulb fly ..... *Merodon equestris* (F.)
native elm bark beetle ..... *Hylurgopinus rufipes* (Eich.)
navel orange worm ..... *Myelois venipars* Dyar
negro bug ..... *Allocoris pulicaria* (Germ.)
New Guinea sugarcane weevil ..... *Rhabdocnemis obscura* (Bdv.)
New York weevil ..... *Ithycerus noveboracensis* (Forst.)
northeastern sawyer ..... *Monochamus notatus* (Drury)
northern cattle grub ..... *Hypoderma bovis* Deg.
northern house mosquito ..... *Culex pipiens* L.
northern mole cricket ..... *Gryllotalpa hexadactyla* Perty
northwestern floodwater mosquito ..... *Aedes aldrichi* Dyar & Knab
Norway maple aphid ..... *Periphyllus lyropictus* (Kess.)
nose botfly ..... *Gastrophilus haemorrhoidalis* (L.)
nutgrass armyworm ..... *Spodoptera mauritia* (Bdv.)
Nuttal's blister beetle ..... *Lytta nuttalli* Say

oak sapling borer ..... *Hammoderus tessellatus* (Hald.)
oak timber worm ..... *Platysystrophus minutus* (Drury)
oblique-banded leaf roller ..... *Cacoecia rosaceana* (Harr.)
obscure scale ..... *Chrysomphalus obscurus* (Comst.)
odorous house ant ..... *Tapinoma sessile* (Say)
oleander scale ..... *Aspidiotus hederae* (Vallot)
olive fruitfly ..... *Dacus oleae* Gmel.
onion maggot ..... *Hylemyia antiqua* Meig.
onion thrips ..... *Thrips tabaci* Lind.
orange dog ..... *Papilio thoas* L.
orange-striped oak worm ..... *Anisota senatoria* (S. & A.)
orange tortrix ..... *Argyrotaenia citrana* (Fern.)
orchid fly ..... *Eurytoma orchidearum* (Westw.)
Oregon fur sawyer ..... *Monochamus oregonensis* Lec.
Oregon wireworm ..... *Melanotus oregonensis* (Lec.)
oriental beetle ..... *Anomala orientalis* Wtrh.
oriental cockroach ..... *Blatta orientalis* L.
oriental fruit moth ..... *Grapholitha molesta* (Busck)
oriental housefly ..... *Musca vicina* Macq.
oriental moth ..... *Cnidocampa flavescens* (Walk.)
oriental rat flea ..... *Xenopsylla cheopis* (Rothsch.)
oystershell scale ..... *Lepidosaphes ulmi* (L.)

Pacific coast tick ..... *Dermacentor occidentalis* Neum.
Pacific coast wireworm ..... *Limonius canus* Lec.
Pacific flatheaded borer ..... *Chrysobothris mali* Horn
painted beauty ..... *Cynthia virginiensis* (Drury)
painted lady ..... *Cynthia cardui* (L.)
pale-sided cutworm ..... *Feltia malefida* (Guen.)
pale-striped flea beetle ..... *Systena blanda* Melsh.
pale tussock moth ..... *Halisidota tessellaris* (S. & A.)

pale western cutworm ..... *Porosagrotis orthogonia* (Morr.)
pales weevil ..... *Hylobius pales* (Hbst.)
palmerworm ..... *Dichomeris ligulella* Hbn.
pandora moth ..... *Coloradia pandora* Blake
papaya fruitfly ..... *Toxotrypana curricauda* Gerst.
parlatoria date scale ..... *Parlatoria blanchardii* (Targ.)
parsley worm ..... *Papilio polyxenes* F.
parsnip webworm ..... *Depressaria heracliana* (Deg.)
pavement ant ..... *Tetramorium caespitum* (L.)
pea aphid ..... *Illinoia pisi* (Kltb.)
pea moth ..... *Laspeyresia nigricana* (Steph.)
pea weevil ..... *Bruchus pisorum* (L.)
peach bark beetle ..... *Phthorophloeus limnaris* (Harr.)
peach borer ..... *Conopia exitiosa* (Say)
peach twig borer ..... *Anarsia lineatella* Zell.
pear fruit borer ..... *Nephopteryx rubrizonella* Rag.
pear leaf blister mite ..... *Eriophyes pyri* Pgst.
pear midge ..... *Contarinia pyrivora* (Riley)
pear plant bug ..... *Lygus communis* Knight
pear psylla ..... *Psyllia pyricola* (Foerst.)
pear slug ..... *Eriocampoides limacina* (Retz.)
pear thrips ..... *Taeniothrips inconsequens* (Uzel)
pecan budmoth ..... *Gretchena bolliana* (Sling.)
pecan carpenter worm ..... *Cossula magnifica* (Stkr.)
pecan cigar casebearer ..... *Coleophora caryaefoliella* Clem.
pecan leaf casebearer ..... *Acrobasis juglandis* (LeB.)
pecan nut casebearer ..... *Acrobasis caryae* Grote
pecan phylloxera ..... *Phylloxera devastatrix* Perg.
pecan weevil ..... *Curculio caryae* (Horn)
pepper-and-salt moth ..... *Amphidasis cognataria* Guen.
pepper weevil ..... *Anthonomus eugenii* Cano
peppergrass beetle ..... *Galeruca externa* Say
periodical cicada ..... *Magicicada septendecim* (L.)
persimmon psylla ..... *Trioza diospyri* (Ashm.)
Pharaoh's ant ..... *Monomorium pharaonis* (L.)
pickleworm ..... *Diaphania nitidalis* (Stoll)
pigeon fly ..... *Pseudolynchia maura* (Bigot)
pigeon tremex ..... *Tremex columba* (L.)
pine bark aphid ..... *Pineus strobi* Htg.
pine butterfly ..... *Neophasia menapia* (Feld.)
pine needle scale ..... *Chionaspis pinifoliae* (Fitch)
pine tube moth ..... *Argyrotaenia pinatubana* (Kearf.)
pineapple mealybug ..... *Pseudococcus brevipes* (Ckll.)
pineapple scale ..... *Diaspis bromeliae* (Kern.)
pineapple weevil ..... *Metamasius ritchiei* Marshall
pink bollworm ..... *Pectinophora gossypiella* (Saund.)
pinyon cone beetle ..... *Conophthorus edulis* Hopk.
pistol casebearer ..... *Coleophora malivorella* Riley
pitch twig moth ..... *Petrova comstockiana* (Fern.)
pitcherplant mosquito ..... *Wyeomyia smithii* (Coq.)
Plains false wireworm ..... *Eleodes opaca* (Say)
plum curculio ..... *Conotrachelus nenuphar* (Hbst.)
plum gouger ..... *Anthonomus scutellaris* Lec.
polyphemus moth ..... *Telea polyphemus* (Cram.)
pomace fly ..... *Drosophila ampelophila* Loew
ponderosa pine cone beetle ..... *Conophthorus ponderosae* Hopk.
poplar and willow borer ..... *Cryptorhynchus lapathi* (L.)
poplar borer ..... *Saperda calcarata* Say
poplar vagabond aphid ..... *Mordwilkoja vagabunda* (Walsh)
potato aphid ..... *Illinoia solanifolii* (Ashm.)
potato flea beetle ..... *Epitrix cucumeris* Harr.
potato leafhopper ..... *Empoasca fabae* (Harr.)

potato stalk borer ..... *Trichobaris trinotata* (Say)
potato stem borer ..... *Hydroecia micacea* (Esp.)
potato tuber worm ..... *Gnorimoschema operculella* (Zell.)
poultry bug ..... *Haematosiphon sinodoru* (Duges)
prairie flea beetle ..... *Altica canadensis* Gent.
prairie grain wireworm ..... *Ludius aereipennis* (Kby.)
privet leaf miner ..... *Gracilaria cuculipennella* Hbn.
promethea moth ..... *Callosamia promethea* (Drury)
Puget Sound wireworm ..... *Ludius suckleyi* (Lec.)
purple scale ..... *Lepidosaphes beckii* (Newm.)
Putnam's scale ..... *Aspidiotus ancylus* (Putn.)
puss caterpillar ..... *Megalopyge opercularis* (S. & A.)
pyriform scale ..... *Protopulvinaria pyriformis* Ckll.

quince curculio ..... *Conotrachelus crataegi* Walsh

rabbit louse ..... *Haemodipsus ventricosus* Denny
rabbit tick ..... *Haemaphysalis leporis-palustris* Pack.
raisin moth ..... *Ephestia figulilella* Greg.
range caterpillar ..... *Hemileuca oliviae* Ckll.
range crane fly ..... *Tipula simplex* Doane
rapid plant bug ..... *Adelphocoris rapidus* (Say)
raspberry cane borer ..... *Oberea bimaculata* (Oliv.)
raspberry cane maggot ..... *Pegomyia rubivora* (Coq.)
raspberry fruitworm ..... *Byturus unicolor* Say
raspberry leaf roller ..... *Exartema permundanum* Clem.
raspberry root borer ..... *Bembecia marginata* (Harr.)
raspberry sawfly ..... *Monophadnoides rubi* (Harr.)
rat flea ..... *Nosopsyllus fasciatus* (Bosc.)
red admiral ..... *Cynthia atlanta* (L.)
red-backed cutworm ..... *Euxoa ochrogaster* (Guen.)
red-banded leaf roller ..... *Argyrotaenia velutiana* (Walk.)
red-banded thrips ..... *Selenothrips rubrocinctus* (Giard)
red carpenter ant ..... *Camponotus herculeanus pennsylvanicus ferrugineus* (F.)
red date scale ..... *Phoenicococcus marlatti* Ckll.
red elm bark weevil ..... *Magdalis armicollis* (Say)
red flour beetle ..... *Tribolium castaneum* (Hbst.)
red harvester ant ..... *Pogonomyrmex barbatus* (F. Smith)
red-headed ash borer ..... *Neoclytus acuminatus* (F.)
red-headed pine sawfly ..... *Neodiprion lecontei* (Fitch)
red-humped caterpillar ..... *Schizura concinna* (S. & A.)
red-legged flea beetle ..... *Derocrepis erythropus* (Melsh.)
red-legged grasshopper ..... *Melanoplus femur-rubrum* (Deg.)
red-legged ham beetle ..... *Necrobia rufipes* (Deg.)
red milkweed beetle ..... *Tetraopes tetrophthalmus* (Forst.)
red-necked cane borer ..... *Agrilus ruficollis* (F.)
red pine cone beetle ..... *Conophthorus resinosae* Hopk.
red-shouldered ham beetle ..... *Necrobia ruficollis* (F.)
red-tailed tachina ..... *Winthemia quadripustulata* (F.)
red turnip beetle ..... *Entomoscelis adonidis* (Pallas)
red turpentine beetle ..... *Dendroctonus valens* Lec.
red-winged pine beetle ..... *Dendroctonus rufipennis* (Kby.)
regal moth ..... *Citheronia regalis* (F.)
resplendent shield bearer ..... *Coptodisca splendoriferella* (Clem.)
rhododendron lacebug ..... *Stephanitis rhododendri* Horv.
rhubarb curculio ..... *Lixus concavus* Say
rice stalk borer ..... *Chilo plejadellus* Zinck.
rice water weevil ..... *Lissorhoptrus simplex* (Say)
rice weevil ..... *Sitophilus oryzae* (L.)
ring-legged earwig ..... *Euborellia annulipes* (Lucas)
Rocky Mountain grasshopper ..... *Melanoplus mexicanus spretus* (Walsh)
rose aphid ..... *Macrosiphum rosae* (L.)

rose chafer	*Macrodactylus subspinosus* (F.)
rose curculio	*Rhynchites bicolor* (F.)
rose leaf beetle	*Nodonota puncticollis* Say
rose leafhopper	*Typhlocyba rosae* (L.)
rose midge	*Dasyneura rhodophaga* (Coq.)
rose root gall	*Rhodites radicum* O. S.
rose sawfly	*Caliroa aethiops* (F.)
rose scale	*Aulacaspis rosae* (Bouché)
rosy apple aphid	*Anuraphis roseus* (Baker)
roundheaded apple tree borer	*Saperda candida* F.
roundheaded fir borer	*Tetropium abietis* Fall
roundheaded pine beetle	*Dendroctonus convexifrons* Hopk.
rusty plum aphid	*Hysteroneura setariae* (Thos.)
rusty tussock moth	*Notolophus antiqua* (L.)
saddleback caterpillar	*Sibine stimulea* (Clem.)
saddled leafhopper	*Thamnotettix clitellarius* (Say)
saddled prominent	*Heterocampa guttivitta* (Walk.)
salt-marsh caterpillar	*Estigmene acraea* (Drury)
salt-marsh mosquito	*Aedes sollicitans* (Walk.)
sand wireworm	*Horistonotus uhlerii* Horn
San José scale	*Aspidiotus perniciosus* Comst.
sapwood timber worm	*Hylecoetus lugubris* Say
satin moth	*Stilpnotia salicis* (L.)
saw-toothed grain beetle	*Oryzaephilus surinamensis* (L.)
Say's blister beetle	*Pomphopoea sayi* Lec.
Say's stinkbug	*Chlorochroa sayi* Stål
scab mite	*Psoroptes communis* Feurst.
scaly leg mite	*Cnemidocoptes mutans* Robin
screwworm	*Cochliomyia americana* C. & P.
scurfy scale	*Chionaspis furfura* (Fitch)
secondary screwworm	*Cochliomyia macellaria* F.
seed-corn beetle	*Agonoderus lecontei* Chaud.
seed-corn maggot	*Hylemyia cilicrura* Rond.
sequoia pitch moth	*Vespamima sequoiae* (Hy. Edw.)
serpentine leaf miner	*Agromyza pusilla* Meig.
sheep botfly	*Oestris ovis* L.
sheep follicle mite	*Demodex canis ovis* Raill.
sheep scab mite	*Psoroptes ovis* Her.
sheep tick	*Melophagus ovinus* (L.)
short-nosed cattle louse	*Haematopinus eurysternus* Nitz.
shot-hole borer	*Scolytus rugulosus* Ratz.
silkworm	*Bombyx mori* L.
silky ant	*Formica fusca subsericea* Say
silky cane weevil	*Metamasius sericeus* (Oliv.)
silverfish	*Lepisma saccharina* L.
sinuate pear tree borer	*Agrilus sinuatus* (Oliv.)
Sitka spruce beetle	*Dendroctonus obesus* (Mann.)
Sitka spruce weevil	*Pissodes sitchensis* Hopk.
six-spotted leafhopper	*Cicadula dirisa* (Uhl.)
six-spotted mite	*Tetranychus sexmaculatus* Riley
slender duck louse	*Esthiopterum crassicorne* (Scop.)
slender pigeon louse	*Columbicola columbae* (L.)
small pigeon louse	*Goniocotes bidentatus* Scop.
smaller European elm bark beetle	*Scolytus multistriatus* Marsham
smaller Mexican pine beetle	*Dendroctonus mexicanus* Hopk.
smartweed borer	*Pyrausta ainsliei* Heinr.
smut beetle	*Phalacrus politus* Melsh.
snowball aphid	*Aphis viburnicola* Gill.
snowy tree cricket	*Oecanthus niveus* (Deg.)
soft scale	*Coccus hesperidum* L.
sorghum midge	*Contarinia sorghicola* (Coq.)

sorghum webworm ..... *Celama sorghiella* (Riley)
southern armyworm ..... *Prodenia eridania* (Cram.)
southern beet webworm ..... *Pachyzancla bipunctalis* (F.)
southern buffalo gnat ..... *Eusimulium pecuarum* (Riley)
southern cabbage worm ..... *Ascia protodice* (Bdv. & Lec.)
southern corn rootworm ..... *Diabrotica duodecimpunctata* (F.)
southern cornstalk borer ..... *Diatraea crambidoides* (Grote)
southern green stinkbug ..... *Nezara viridula* (L.)
southern house mosquito ..... *Culex quinquefasciatus* Say
southern mole cricket ..... *Scapteriscus acletus* R. & H.
southern pine beetle ..... *Dendroctonus frontalis* Zimm.
southern pine sawyer ..... *Monochamus titillator* (F.)
southwestern corn borer ..... *Diatraea grandiosella* Dyar
southwestern pine beetle ..... *Dendroctonus barberi* Hopk.
Spanish fly ..... *Lytta vesicatoria* (L.)
spinach leaf miner ..... *Pegomyia hyoscyami* Panz.
spined soldier bug ..... *Podisus maculiventris* (Say)
spiny oak worm ..... *Anisota stigma* F.
spotted asparagus beetle ..... *Crioceris duodecimpunctata* (L.)
spotted beet webworm ..... *Hymenia perspectalis* (Hbn.)
spotted blister beetle ..... *Epicauta maculata* (Say)
spotted cucumber beetle ..... *Diabrotica duodecimpunctata* (F.)
spotted cutworm ..... *Agrotis c-nigrum* (L.)
spotted pine sawyer ..... *Monochamus maculosus* Hald.
spotted tussock moth ..... *Halisidota maculata* (Harr.)
spring cankerworm ..... *Paleacrita vernata* (Peck)
spruce aphid ..... *Aphis abietina* Walk.
spruce budworm ..... *Cacoecia fumiferana* (Clem.)
spruce sawfly ..... *Neodiprion abietis* (Harr.)
square-necked grain beetle ..... *Silvanus gemellatus* Duv.
squash beetle ..... *Epilachna borealis* (F.)
squash borer ..... *Melittia satyriniformis* Hbn.
squash bug ..... *Anasa tristis* (Deg.)
stablefly ..... *Stomoxys calcitrans* (L.)
stalk borer ..... *Papaipema nebris nitela* (Guen.)
steel-blue ladybeetle ..... *Orcus chalybeus* (Bdv.)
sticktight flea ..... *Echidnophaga gallinacea* (Westw.)
stink beetle ..... *Nomius pygmaeus* (Dej.)
strawberry aphid ..... *Capitophorus fragaefolii* (Ckll.)
strawberry crown borer ..... *Tyloderma fragariae* (Riley)
strawberry crown moth ..... *Synanthedon rutilans* (Hy. Edw.)
strawberry fruitworm ..... *Cnephasia longana* (Haw.)
strawberry leaf roller ..... *Ancylis comptana* (Froel.)
strawberry root aphid ..... *Aphis forbesi* Weed
strawberry root weevil ..... *Brachyrhinus ovatus* (L.)
strawberry weevil ..... *Anthonomus signatus* Say
strawberry whitefly ..... *Trialeurodes packardi* (Morrill)
straw itch mite ..... *Pediculoides ventricosus* Newp.
striped blister beetle ..... *Epicauta vittata* F.
striped cucumber beetle ..... *Diabrotica vittata* (F.)
striped cutworm ..... *Euxoa tessellata* (Harr.)
striped flea beetle ..... *Phyllotreta vittata* (F.)
striped garden caterpillar ..... *Polia legitima* (Grote)
striped horsefly ..... *Tabanus lineola* F.
suckfly ..... *Dicyphus minimus* Uhl.
sucking horse louse ..... *Haematopinus asini* (L.)
sugar-beet root aphid ..... *Pemphigus betae* Doane
sugar-beet wireworm ..... *Limonius californicus* (Mann.)
sugarcane beetle ..... *Euetheola rugiceps* (Lec.)
sugarcane borer ..... *Diatraea saccharalis* (F.)
sugarcane leafhopper ..... *Perkinsiella saccharicida* Kirk.
sugarcane leaf roller ..... *Omiodes accepta* (Butl.)

sugar maple borer	*Glycobius speciosus* (Say)
sugar pine cone beetle	*Conophthorus lambertianae* Hopk.
sunflower beetle	*Xygogramma exclamationis* (F.)
sunflower maggot	*Straussia longipennis* (Wied.)
Surinam roach	*Pycnoscelus surinamensis* (L.)
swallow bug	*Oeciacus vicarius* Horv.
sweetpotato flea beetle	*Chaetocnema confinis* Crotch
sweetpotato hornworm	*Herse cingulata* (F.)
sweetpotato leaf miner	*Bedellia orchilella* Wlsm.
sweetpotato leaf roller	*Pilocrocis tripunctata* (F.)
sweetpotato vine borer	*Omphisa anastomosalis* (Guen.)
sweetpotato weevil	*Cylas formicarius* (F.)
sweetpotato whitefly	*Bemisia inconspicua* (Quaint.)
Tahitian coconut weevil	*Diocalandra taitensis* Guer.
tarnished plant bug	*Lygus pratensis* (L.)
ten-lined June beetle	*Polyphylla decemlineata* (Say)
terrapin scale	*Lecanium nigrofasciatum* Perg.
thief ant	*Solenopsis molesta* (Say)
thistle aphid	*Anuraphis cardui* (L.)
three-banded leafhopper	*Erythroneura tricincta* Fitch
three-cornered alfalfa hopper	*Stictocephala festina* (Say)
three-lined potato beetle	*Lema trilineata* (Oliv.)
throat botfly	*Gastrophilus nasalis* (L.)
thurberia weevil	*Anthonomus grandis thurberiae* Pierce
tiger swallowtail	*Papilio glaucus turnus* (L.)
toadbug	*Gelastocoris oculatus* (F.)
tobacco budworm	*Heliothis virescens* (F.)
tobacco flea beetle	*Epitrix parvula* (F.)
tobacco moth	*Ephestia elutella* (Hbn.)
tobacco thrips	*Frankliniella fusca* (Hinds)
tobacco worm	*Protoparce quinquemaculata* (Haw.)
tomato pinworm	*Gnorimoschema lycopersicella* (Busck)
tomato worm	*Protoparce sexta* (Johan.)
tropical horse tick	*Dermacentor nitens* Neum.
tropical rat mite	*Lyponyssus bacoti* (Hirst)
tule beetle	*Agonum maculicollis* Dej.
tuliptree scale	*Toumeyella liriodendri* (Gmel.)
turkey gnat	*Simulium meridionale* Riley
turnip aphid	*Rhopalosiphum pseudobrassicae* (Davis)
twice-stabbed ladybeetle	*Chilocorus bivulnerus* Muls.
twig girdler	*Oncideres cingulatus* (Say)
twig pruner	*Hypermallus villosus* (F.)
two-lined chestnut borer	*Agrilus bilineatus* (Web.)
two-spotted ladybeetle	*Adalia bipunctata* (L.)
two-striped grasshopper	*Melanoplus bivittatus* (Say)
two-striped walkingstick	*Anisomorpha buprestoides* (Stoll)
ugly-nest caterpillar	*Cacoecia cerasivorana* (Fitch)
unicorn caterpillar	*Schizura unicornis* (S. & A.)
vagabond crambus	*Crambus vulgivagellus* Clem.
varied carpet beetle	*Anthrenus verbasci* (L.)
variegated cutworm	*Lycophotia margaritosa saucia* Hbn.
vedalia	*Rodolia cardinalis* (Muls.)
vegetable weevil	*Listroderes obliquus* Klug
velvetbean caterpillar	*Anticarsia gemmatilis* (Hbn.)
vetch bruchid	*Bruchus brachialis* Fahraeus
viceroy	*Basilarchia archippus* (Cram.)
violet aphid	*Micromyzus violae* (Perg.)
violet sawfly	*Emphytina canadensis* (Kby.)
walkingstick	*Diapheromera femorata* (Say)

walnut aphid ..... *Chromaphis juglandicola* (Kltb.)
walnut blister mite ..... *Eriophyes tristriatus erineus* Nal.
walnut caterpillar ..... *Datana integerrima* G. & R.
walnut husk fly ..... *Rhagoletis completa* Cress.
walnut scale ..... *Aspidiotus juglans-regiae* Comst.
walnut sphinx ..... *Cressonia juglandis* (S. & A.)
watercress leaf beetle ..... *Phaedon aeruginosus* Suffr.
watercress sowbug ..... *Mancasellus brachyurus* Harger
wax moth ..... *Galleria mellonella* (L.)
webbing clothes moth ..... *Tineola biselliella* (Hum.)
western balsam bark beetle ..... *Dryocoetes confusus* Swaine
western black flea beetle ..... *Phyllotreta pusilla* Horn
western cedar borer ..... *Trachykele blondeli* Marseul
western chicken flea ..... *Ceratophyllus niger* Fox
western chinch bug ..... *Blissus occiduus* Barber
western field wireworm ..... *Limonius infuscatus* Mots.
western grape rootworm ..... *Adoxus obscurus* (L.)
western grape skeletonizer ..... *Harrisina brillians* B. & McD.
western peach borer ..... *Conopia opalescens* (Hy. Edw.)
western pine beetle ..... *Dendroctonus brevicomis* Lec.
western potato flea beetle ..... *Epitrix subcrinita* Lec.
western spotted cucumber beetle ..... *Diabrotica soror* Lec.
western striped cucumber beetle ..... *Diabrotica trivittata* (Mann.)
western striped flea beetle ..... *Phyllotreta ramosa* (Crotch)
western tent caterpillar ..... *Malacosoma pluvialis* (Dyar)
western tree hole mosquito ..... *Aedes varipalpus* (Coq.)
western tussock moth ..... *Hemerocampa vetusta* (Bdv.)
West Indian cane weevil ..... *Metamasius hemipterus* (L.)
West Indian fruitfly ..... *Anastrepha fraterculus* (Wied.)
West Indian sweetpotato weevil ..... *Euscepes batatae* (Wtrh.)
wheat jointworm ..... *Harmolita tritici* (Fitch)
wheat midge ..... *Contarinia tritici* (Kby.)
wheat stem maggot ..... *Meromyza americana* Fitch
wheat stem sawfly ..... *Cephus cinctus* Nort.
wheat straw worm ..... *Harmolita grandis* (Riley)
wheat wireworm ..... *Agriotes mancus* (Say)
wheathead armyworm ..... *Neleucania albilinea* (Hbn.)
wheel bug ..... *Arilus cristatus* (L.)
white apple leafhopper ..... *Typhlocyba pomaria* McAtee
white cutworm ..... *Euxoa scandens* (Riley)
white-lined sphinx ..... *Sphinx lineata* F.
white-marked spider beetle ..... *Ptinus fur* L.
white-marked tussock moth ..... *Hemerocampa leucostigma* (S. & A.)
white peach scale ..... *Aulacaspis pentagona* (Targ.)
white-pine cone beetle ..... *Conophthorus coniperda* (Schwarz)
white-pine weevil ..... *Pissodes strobi* (Peck)
white-spotted sawyer ..... *Monochamus scutellatus* (Say)
willow sawfly ..... *Pteronidea ventralis* (Say)
winter tick ..... *Dermacentor albipictus* (Pack.)
w-marked cutworm ..... *Agrotis unicolor* (Walk.)
woolly alder aphid ..... *Prociphilus tessellatus* (Fitch)
woolly apple aphid ..... *Eriosoma lanigerum* (Hausm.)
woolly elm aphid ..... *Eriosoma americanum* Riley
woolly pear aphid ..... *Eriosoma pyricola* Baker
woolly whitefly ..... *Aleurothrixus howardi* (Quaint.)

yellow-fever mosquito ..... *Aedes aegypti* (L.)
yellow-headed cutworm ..... *Septis arctica* (Bdv.)
yellow-headed fireworm ..... *Peronea minuta* (Rob.)
yellow-headed spruce sawfly ..... *Pachynematus ocreatus* Hgtn.
yellow mealworm ..... *Tenebrio molitor* L.
yellow-necked caterpillar ..... *Datana ministra* (Drury)

yellow-striped armyworm ..... *Prodenia ornithogalli* Guen.
yellow woolly bear ..... *Diacrisia virginica* (F.)
Yosemite bark weevil ..... *Pissodes yosemite* Hopk.
yucca moth ..... *Tegeticula yuccasella* (Riley)

zebra caterpillar ..... *Mamestra picta* Harr.

Insects Listed by Scientific Names

Acanthoscelides obtectus (Say) ..... bean weevil
Acrobasis caryae Grote ..... pecan nut casebearer
Acrobasis juglandis (LeB.) ..... pecan leaf casebearer
Acronicta americana (Harr.) ..... American dagger moth
Acrosternum hilaris (Say) ..... green stinkbug
Adalia bipunctata (L.) ..... two-spotted ladybeetle
Adelphocoris rapidus (Say) ..... rapid plant bug
Adoxus obscurus (L.) ..... western grape rootworm
Aedes aegypti (L.) ..... yellow-fever mosquito
Aedes aldrichi Dyar & Knab ..... northwestern floodwater mosquito
Aedes cantator (Coq.) ..... brown salt-marsh mosquito
Aedes hirsuteron (Theob.) ..... floodwater mosquito
Aedes sollicitans (Walk.) ..... salt-marsh mosquito
Aedes squamiger (Coq.) ..... California salt-marsh mosquito
Aedes varipalpus (Coq.) ..... western tree hole mosquito
Agonoderus lecontei Chaud. ..... seed-corn beetle
Agonum maculicollis Dej. ..... tule beetle
Agrilus anxius Gory ..... bronzed birch borer
Agrilus bilineatus (Web.) ..... two-lined chestnut borer
Agrilus ruficollis (F.) ..... red-necked cane borer
Agrilus sinuatus (Oliv.) ..... sinuate pear tree borer
Agriotes mancus (Say) ..... wheat wireworm
Agromyza lantanae Froggatt ..... lantana seed fly
Agromyza parvicornis Loew ..... corn blotch leaf miner
Agromyza pusilla Meig. ..... serpentine leaf miner
Agromyza simplex Loew ..... asparagus miner
Agrotis c-nigrum (L.) ..... spotted cutworm
Agrotis fennica Tausch. ..... black army cutworm
Agrotis unicolor (Walk.) ..... w-marked cutworm
Agrotis ypsilon (Rott.) ..... black cutworm
Alabama argillacea (Hbn.) ..... cotton leaf worm
Alaus oculatus (L.) ..... eyed click beetle
Aleurocanthus woglumi Ashby ..... citrus blackfly
Aleurothrixus howardi (Quaint.) ..... woolly whitefly
Allocoris pulicaria (Germ.) ..... negro bug
Alniphagus aspericollis (Lec.) ..... alder bark beetle
Alsophila pometaria (Harr.) ..... fall cankerworm
Altica bimarginata Say ..... alder flea beetle
Altica canadensis Gent. ..... prairie flea beetle
Altica chalybea Ill. ..... grape flea beetle
Alypia octomaculata (F.) ..... eight-spotted forester
Amblyomma americanum (L.) ..... lone star tick
Amblyomma maculatum Koch ..... Gulf coast tick
Ametastegia glabrata (Fall.) ..... dock sawfly
Ampeloglypter sesostris (Lec.) ..... grape cane gall maker
Amphidasis cognataria Guen. ..... pepper-and-salt moth
Anabrus simplex Hald. ..... Mormon cricket
Anaphothrips obscurus (Müll.) ..... grass thrips
Anarsia lineatella Zell. ..... peach twig borer
Anasa tristis (Deg.) ..... squash bug
Anastrepha fraterculus (Wied.) ..... West Indian fruitfly
Anastrepha ludens (Loew) ..... Mexican fruitfly
Anastrepha pallens Coq. ..... bumelia fruitfly

Ancylis comptana (Froel.) ..... strawberry leaf roller
Anisomorpha buprestoides (Stoll) ..... two-striped walkingstick
Anisota rubicunda (F.) ..... green-striped maple worm
Anisota senatoria (S. & A.) ..... orange-striped oak worm
Anisota stigma (F.) ..... spiny oak worm
Anocomis lignea (F.) ..... cedar tree borer
Anomala orientalis Wtrh. ..... oriental beetle
Anopheles quadrimaculatus Say ..... common malarial mosquito
Anthonomus eugenii Cano ..... pepper weevil
Anthonomus grandis Boh. ..... boll weevil
Anthonomus grandis thurberiae Pierce ..... thurberia weevil
Anthonomus musculus Say ..... cranberry weevil
Anthonomus scutellaris Lec. ..... plum gouger
Anthonomus signatus Say ..... strawberry weevil
Anthrenus scrophulariae (L.) ..... carpet beetle
Anthrenus verbasci (L.) ..... varied carpet beetle
Anticarsia gemmatilis (Hbn.) ..... velvetbean caterpillar
Anuraphis bakeri (Cowen) ..... clover aphid
Anuraphis cardui (L.) ..... thistle aphid
Anuraphis maidi-radicis (Forbes) ..... corn root aphid
Anuraphis persicae-niger (Smith) ..... black peach aphid
Anuraphis roseus (Baker) ..... rosy apple aphid
Aphis abietina Walk. ..... spruce aphid
Aphis forbesi Weed ..... strawberry root aphid
Aphis gossypii Glov. ..... cotton aphid, melon aphid
Aphis hederae Kltb. ..... ivy aphid
Aphis illinoisensis Shim. ..... grapevine aphid
Aphis maidis Fitch ..... corn leaf aphid
Aphis medicaginis Koch ..... cowpea aphid
Aphis pomi Deg. ..... apple aphid
Aphis rumicis L. ..... bean aphid
Aphis viburnicola Gill. ..... snowball aphid
Apis mellifera L. ..... honeybee
Araecerus fasciculatus (Deg.) ..... coffee-bean weevil
Argas miniatus Koch ..... fowl tick
Argyresthis conjugella Zell. ..... apple fruit moth
Argyresthia thuiella (Pack.) ..... arborvitae leaf miner
Argyrotaenia citrana (Fern.) ..... orange tortrix
Argyrotaenia juglandana (Fern.) ..... hickory leaf roller
Argyrotaenia mariana (Fern.) ..... gray-banded leaf roller
Argyrotaenia pinatubana (Kearf.) ..... pine tube moth
Argyrotaenia velutinana (Walk.) ..... red-banded leaf roller
Arilus cristatus (L.) ..... wheel bug
Asarcopus palmarum Horv. ..... date bug
Ascia protodice (Bdv. & Lec.) ..... southern cabbage worm
Ascia rapae (L.) ..... imported cabbage worm
Asphondylia websteri Felt ..... alfalfa gall midge
Aspidiotus ancylus (Putn.) ..... Putnam's scale
Aspidiotus camelliae Sign. ..... greedy scale
Aspidiotus forbesi Johns. ..... cherry scale
Aspidiotus hederae (Vallot) ..... oleander scale
Aspidiotus howardi Ckll. ..... Howard's scale
Aspidiotus juglans-regiae Comst. ..... walnut scale
Aspidiotus ostreaeformis Curt. ..... European fruit scale
Aspidiotus perniciosus Comst. ..... San José scale
Aspidiotus uvae Comst. ..... grape scale
Attagenus piceus (Oliv.) ..... black carpet beetle
Aulacaspis pentagona (Targ.) ..... white peach scale
Aulacaspis rosae (Bouché) ..... rose scale
Autographa brassicae (Riley) ..... cabbage looper
Autographa californica (Speyer) ..... alfalfa looper
Autographa egena (Guen.) ..... bean leaf skeletonizer

Autographa falcifera (Kby.) ..... celery looper
Automeris io (F.) ..... io moth
Autoserica castanea (Arrow) ..... Asiatic garden beetle

Bactrocera cucurbitae Coq. ..... melonfly
Barathra configurata (Walk.) ..... bertha armyworm
Basilarchia archippus (Cram.) ..... viceroy
Bedellia orchilella Wlsm. ..... sweetpotato leaf miner
Bembecia marginata (Harr.) ..... raspberry root borer
Bemisia inconspicua (Quaint.) ..... sweetpotato whitefly
Blatta orientalis L. ..... oriental cockroach
Blattella germanica (L.) ..... German cockroach
Blissus hirtus Montd. ..... hairy chinch bug
Blissus leucopterus (Say) ..... chinch bug
Blissus occiduus Barber ..... western chinch bug
Bombyx mori L. ..... silkworm
Boophilus annulatus (Say) ..... cattle tick
Bourletiella hortensis (Fitch) ..... garden springtail
Bovicola bovis (Nitz.) ..... cattle biting-louse
Brachyrhinus ligustici (L.) ..... alfalfa snout beetle
Brachyrhinus ovatus (L.) ..... strawberry root weevil
Brachyrhinus sulcatus (F.) ..... black vine weevil
Brachystola magna (Gir.) ..... lubber grasshopper
Bregmatothrips iridis Watson ..... iris thrips
Brevicoryne brassicae (L.) ..... cabbage aphid
Bruchophagus gibbus (Boh.) ..... clover seed chalcid
Bruchus brachialis Fahraeus ..... vetch bruchid
Bruchus pisorum (L.) ..... pea weevil
Bruchus rufimanus Boh. ..... broadbean weevil
Bryobia practiosa Koch ..... clover mite
Bucculatrix canadensisella Chamb. ..... birch skeletonizer
Bucculatrix thurberiella Busck ..... cotton leaf perforator
Byturus unicolor Say ..... raspberry fruitworm

Cacoecia argyrospila (Walk.) ..... fruit tree leaf roller
Cacoecia cerasivorana (Fitch) ..... ugly-nest caterpillar
Cacoecia fumiferana (Clem.) ..... spruce budworm
Cacoecia rosaceana (Harr.) ..... oblique-handed leaf roller
Caenurgia erechtea (Cram.) ..... forage looper
Calendra spp. ..... corn billbugs
Caliroa aethiops (F.) ..... rose sawfly
Callimome druparum (Boh.) ..... apple seed chalcid
Calliphora spp. ..... bluebottle flies
Callosamia promethea (Drury) ..... promethea moth
Callosobruchus maculatus (F.) ..... cowpea weevil
Calosoma calidum (F.) ..... fiery hunter
Calpodes ethlius (Cram.) ..... larger canna leaf roller
Camnula pellucida (Scudd.) ..... clear-winged grasshopper
Camponotus herculeanus pennsylvanicus (Deg.) ..... black carpenter ant
Camponotus herculeanus pennsylvanicus ferrugineus (F.) ..... red carpenter ant
Capitophorus fragaefolii (Ckll.) ..... strawberry aphid
Capitophorus ribis (L.) ..... currant aphid
Carpocapsa pomonella L. ..... codling moth
Carpoglyphus passularum Her. ..... dried fruit mite
Carpophilus dimidiatus (F.) ..... corn sap beetle
Carpophilus hemipterus (L.) ..... dried fruit beetle
Celama sorghiella (Riley) ..... sorghum webworm
Cephus cinctus Nort. ..... wheat stem sawfly
Cephus pygmaeus (L.) ..... European wheat stem sawfly
Ceratitis capitata Wied. ..... Mediterranean fruitfly
Ceratomia catalpae (Bdv.) ..... catalpa sphinx
Ceratophyllus gallinae Schr. ..... European chicken flea
Ceratophyllus niger Fox ..... western chicken flea

Ceresa bubalus (F.) ..... buffalo treehopper
Ceroplastes cirripediformis Comst. ..... barnacle scale
Ceroplastes floridensis Comst. ..... Florida wax scale
Cerotoma trifurcata (Forst.) ..... bean leaf beetle
Ceutorhynchus quadridens (Panz.) ..... cabbage seedstalk curculio
Ceutorhynchus rapae Gyll. ..... cabbage curculio
Chaetocnema confinis Crotch ..... sweetpotato flea beetle
Chaetocnema ectypa Horn ..... desert corn flea beetle
Chaetocnema pulicaria Melsh. ..... corn flea beetle
Chalcodermus aeneus Boh. ..... cowpea curculio
Chalepus dorsalis Thunb. ..... locust leaf miner
Chelymorpha cassidea (F.) ..... argus tortoise beetle
Chilocorus bivulnerus Muls. ..... twice-stabbed ladybeetle
Chilo plejadellus Zinck. ..... rice stalk borer
Chilo simplex (Butl.) ..... Asiatic rice borer
Chionaspis americana Johns. ..... elm scurfy scale
Chionaspis euonymi Comst. ..... euonymus scale
Chionaspis furfura (Fitch) ..... scurfy scale
Chionaspis pinifoliae (Fitch) ..... pine needle scale
Chirida guttata (Oliv.) ..... mottled tortoise beetle
Chlorochroa sayi Stål ..... Say's stinkbug
Chorizagrotis auxiliaris (Grote) ..... army cutworm
Chromaphis juglandicola (Kltb.) ..... walnut aphid
Chrysobothris femorata (Oliv.) ..... flatheaded apple tree borer
Chrysobothris mali Horn ..... Pacific flatheaded borer
Chrysobothris tranquebarica (Gmel.) ..... Australian pine borer
Chrysomela scripta F. ..... cottonwood leaf beetle
Chyrsomphalus aonidum (L.) ..... Florida red scale
Chrysomphalus aurantii (Mask.) ..... California red scale
Chrysomphalus dictyospermi (Morg.) ..... dictyospermum scale
Chrysomphalus obscurus (Comst.) ..... obscure scale
Chrysomphalus tenebricosus (Comst.) ..... gloomy scale
Chrysops spp. ..... deer flies
Cicadidae ..... cicadas
Cicadula divisa (Uhl.) ..... six-spotted leafhopper
Cimbex americana Leach ..... elm sawfly
Cimex lectularius L. ..... bedbug
Cingilia catenaria (Drury) ..... chain-spotted geometer
Cirphis unipuncta (Haw.) ..... armyworm
Citheronia regalis (F.) ..... hickory horned devil, regal moth
Cladius isomerus Nort. ..... bristly rose slug
Cleora pampinaria (Guen.) ..... cranberry spanworm
Cnemidocoptes gallinae Raill. ..... depluming mite
Cnemidocoptes mutans Robin ..... scaly leg mite
Cnephasia longana (Haw.) ..... strawberry fruitworm
Cnidocampa flavescens (Walk.) ..... oriental moth
Coccus hesperidum L. ..... soft scale
Coccus pseudomagnoliarum (Kuw.) ..... citricola scale
Coccus viridis (Green) ..... green scale
Cochliomyia americana C. & P. ..... screwworm
Cochliomyia macellaria F. ..... secondary screwworm
Colaspis brunnea (F.) ..... grape colaspis
Coleophora caryaefoliella Clem. ..... pecan cigar casebearer
Coleophora fletcherella Fern. ..... cigar casebearer
Coleophora laricella Hbn. ..... larch casebearer
Coleophora limosipennella Dup. ..... elm casebearer
Coleophora malivorella Riley ..... pistol casebearer
Coleophora pruniella Clem. ..... cherry casebearer
Colopha ulmicola (Fitch) ..... elm cockscomb gall
Coloradia pandora Blake ..... pandora moth
Columbicola columbae (L.) ..... slender pigeon louse
Conopia exitiosa (Say) ..... peach borer

Conopia opalescens (Hy. Edw.)	western peach borer
Conophthorus coniperda (Schwarz)	white-pine cone beetle
Conophthorus contortae Hopk.	lodgepole cone beetle
Conophthorus edulis Hopk.	pinyon cone beetle
Conophthorus lambertianae Hopk.	sugar pine cone beetle
Conophthorus ponderosae Hopk.	ponderosa pine cone beetle
Conophthorus radiatae Hopk.	Monterey pine cone beetle
Conophthorus resinosae Hopk.	red pine cone beetle
Conotrachelus crataegi Walsh	quince curculio
Conotrachelus nenuphar (Hbst.)	plum curculio
Contarinia johnsoni Sling.	grape blossom midge
Contarinia pyrivora (Riley)	pear midge
Contarinia sorghicola (Coq.)	sorghum midge
Contarinia tritici (Kby.)	wheat midge
Coptodisca splendoriferella (Clem.)	resplendent shield bearer
Corthylus columbianus Hopk.	Columbian timber beetle
Corydalis cornuta (L.)	dobson fly, hellgrammite
Corythucha gossypii (F.)	cotton lacebug
Cosmopolites sordidus (Germ.)	banana root borer
Cossula magnifica (Stkr.)	pecan carpenter worm
Cotinis nitida (L.)	green June beetle
Crambus caliginosellus Clem.	corn root webworm
Crambus hortuellus (Hbn.)	cranberry girdler
Crambus vulgivagellus Clem.	vagabond crambus
Craponius inaequalis (Say)	grape curculio
Cremastobombycia lantanella Busck	lantana leaf miner
Cressonia juglandis (S. & A.)	walnut sphinx
Crioceris asparagi (L.)	asparagus beetle
Crioceris duodecimpunctata (L.)	spotted asparagus beetle
Cryptococcus fagi (Baer.)	beech scale
Cryptorhynchus lapathi (L.)	poplar and willow borer
Cryptothrips floridensis Watson	camphor thrips
Ctenocephalides canis (Curt.)	dog flea
Ctenocephalides felis (Bouché)	cat flea
Culex pipiens L.	northern house mosquito
Culex quinquefasciatus Say	southern house mosquito
Curculio caryae (Horn)	pecan weevil
Curculio proboscideus F.	large chestnut weevil
Curculio rectus (Say)	chestnut weevil
Cylas formicarius (F.)	sweetpotato weevil
Cyllene robiniae (Forst.)	locust borer
Cynthia atlanta (L.)	red admiral
Cynthia cardui (L.)	painted lady
Cynthia virginiensis (Drury)	painted beauty
Dacus oleae Gmel.	olive fruitfly
Danaus menippe (Hbn.)	monarch butterfly
Dasyneura leguminicola (Lint.)	clover seed midge
Dasyneura rhodophaga (Coq.)	rose midge
Dasyneura trifolii (Loew)	clover leaf midge
Datana integerrima G. & R.	walnut caterpillar
Datana ministra (Drury)	yellow-necked caterpillar
Deinocerites cancer Theob.	crab hole mosquito
Demodex bovis Stiles	cattle follicle mite
Demodex canis Leydig	dog follicle mite
Demodex canis ovis Raill.	sheep follicle mite
Demodex caprae Raill.	goat follicle mite
Demodex cati Megn.	cat follicle mite
Demodex equi Raill.	horse follicle mite
Demodex phylloides Csokor	hog follicle mite
Dendroctonus approximatus Dietz	Colorado pine beetle
Dendroctonus arizonicus Hopk.	Arizona pine beetle
Dendroctonus barberi Hopk.	southwestern pine beetle

Dendroctonus borealis Hopk. Alaska spruce beetle
Dendroctonus brevicomis Lec. western pine beetle
Dendroctonus convexifrons Lopk. roundheaded pine beetle
Dendroctonus engelmanni Hopk. Engelmann spruce beetle
Dendroctonus frontalis Zimm. southern pine beetle
Dendroctonus jeffreyi Hopk. Jeffrey pine beetle
Dendroctonus mexicanus Hopk. smaller Mexican pine beetle
Dendroctonus micans Kug. European spruce beetle
Dendroctonus monticolae Hopk. mountain pine beetle
Dendroctonus murrayanae Hopk. lodgepole pine beetle
Dendroctonus obesus (Mann.) Sitka spruce beetle
Dendroctonus parallelocollis Chap. larger Mexican pine beetle
Dendroctonus piceaperda Hopk. eastern spruce beetle
Dendroctonus ponderosae Hopk. Black Hills beetle
Dendroctonus pseudotsugae Hopk. Douglas fir beetle
Dendroctonus punctatus Lec. Allegheny spruce beetle
Dendroctonus rufipennis (Kby.) red-winged pine beetle
Dendroctonus simplex Lec. eastern larch beetle
Dendroctonus terebrans (Oliv.) black turpentine beetle
Dendroctonus valens Lec. red turpentine beetle
Depressaria heracliana (Deg.) parsnip webworm
Dermacentor albipictus (Pack.) winter tick
Dermacentor nigrolineatus (Pack.) brown winter tick
Dermacentor nitens Neum. tropical horse tick
Dermacentor occidentalis Neum. Pacific Coast tick
Dermacentor variabilis (Say) American dog tick
Dermanyssus gallinae (Deg.) chicken mite
Dermestes lardarius L. larder beetle
Dermestes vulpinus F. hide beetle
Derocrepis erythropus (Melsh.) red-legged flea beetle
Desmia funeralis (Hbn.) grape leaf folder
Diabrotica balteata Lec. banded cucumber beetle
Diabrotica duodecimpunctata (F.) southern corn rootworm, spotted cucumber beetle
Diabrotica longicornis (Say) corn rootworm
Diabrotica soror Lec. western spotted cucumber beetle
Diabrotica trivittata (Mann.) western striped cucumber beetle
Diabrotica vittata (F.) striped cucumber beetle
Diacrisia virginica (F.) yellow woolly bear
Dialeurodes citri Ashm. citrus whitefly
Dialeurodes citrifolii (Morg.) cloudy-winged whitefly
Diaphania hyalinata (L.) melonworm
Diaphania nitidalis (Stoll) pickleworm
Diapheromera femorata (Say) walkingstick
Diarthronomyia hypogaea Loew chrysanthemum gall midge
Diaspis bromeliae (Kern.) pineapple scale
Diaspis echinocacti (Bouché) cactus scale
Diatraea crambidoides (Grote) southern cornstalk borer
Diatraea grandiosella Dyar southwestern corn borer
Diatraea saccharalis (F.) sugarcane borer
Dichelonyx backi (Kby.) green rose chafer
Dichomeris ligulella Hbn. palmerworm
Dicyphus minimus Uhl. suckfly
Diocalandra taitensis Guér. Tahitian coconut weevil
Diprion polytomum (Htg.) European spruce sawfly
Diprion simile (Htg.) introduced pine sawfly
Dissosteira carolina (L.) Carolina grasshopper
Drosophila ampelophila Loew pomace fly
Dryocoetes confusus Swaine western balsam bark beetle
Dysdercus mimulus Hussey Arizona cotton stainer
Dysdercus suturellus (H. S.) cotton stainer

Eacles imperialis (Drury) imperial moth
Echidnophaga gallinacea (Westw.) sticktight flea

Elasmopalpus lignosellus (Zell.) ..... lesser cornstalk borer
Eleodes opaca (Say) ..... Plains false wireworm
Ellopia fiscellaria Guen. ..... hemlock looper
Emphytina canadensis (Kby.) ..... violet sawfly
Emphytus cinctipes Nort. ..... curled rose sawfly
Empoasca fabae (Harr.) ..... potato leafhopper
Empoasca maligna (Walsh) ..... apple leafhopper
Ennomos subsignarius (Hbn.) ..... elm spanworm
Entomoscelis adonidis (Pallas) ..... red turnip beetle
Eomenacanthus stramineus (Nitz.) ..... chicken body louse
Ephestia cautella (Walk.) ..... almond moth
Ephestia elutella (Hbn.) ..... tobacco moth
Ephestia figulilella Greg. ..... raisin moth
Ephestia kuehniella Zell. ..... Mediterranean flour moth
Epicaerus imbricatus (Say) ..... imbricated snout beetle
Epicauta cinerea (Forst.) ..... gray blister beetle
Epicauta maculata (Say) ..... spotted blister beetle
Epicauta marginata (F.) ..... margined blister beetle
Epicauta pennsylvanica (Deg.) ..... black blister beetle
Epicauta vittata F. ..... striped blister beetle
Epicnaptera americana (Harr.) ..... lappet moth
Epidiaspis piricola (Del Guer.) ..... Italian pear scale
Epilachna borealis (F.) ..... squash beetle
Epilachna varivestis Muls. ..... Mexican bean beetle
Epitrix cucumeris Harr. ..... potato flea beetle
Epitrix fuscula Crotch ..... eggplant flea beetle
Epitrix parvula (F.) ..... tobacco flea beetle
Epitrix subcrinita Lec. ..... western potato flea beetle
Epochra canadensis Loew ..... currant fruitfly
Erannis tiliaria (Harr.) ..... lime-tree looper
Eriocampoides limacina (Retz.) ..... pear slug
Eriophyes fici Essig ..... fig mite
Eriophyes gossypii Banks ..... cotton blister mite
Eriophyes pyri Pgst. ..... pear leaf blister mite
Eriophyes ribis Nal. ..... currant bud mite
Eriophyes tristriatus erineus Nal. ..... walnut blister mite
Eriosoma americanum Riley ..... woolly elm aphid
Eriosoma lanigerum (Hausm.) ..... woolly apple aphid
Eriosoma pyricola Baker ..... woolly pear aphid
Erythraspides pygmaca (Say) ..... grape sawfly
Erythroneura comes (Say) ..... grape leafhopper
Erythroneura tricincta Fitch ..... three-banded leafhopper
Esthiopterum crassicorne (Scop.) ..... slender duck louse
Estigmene acraea (Drury) ..... salt-marsh caterpillar
Etiella zinckenella (Treit.) ..... lima beam pod borer
Euborellia annulipes (Lucas) ..... ring-legged earwig
Euetheola rugiceps (Lec.) ..... sugarcane beetle
Eumerus tuberculatus Rond. ..... lesser bulb fly
Euphoria inda (L.) ..... bumble flower beetle
Eurymus eurytheme (Bdv.) ..... alfalfa caterpillar
Eurymus philodice (Godt.) ..... clouded sulphur
Eurytoma orchidearum (Westw.) ..... orchid fly
Euscepes batatae (Wtrh.) ..... West Indian sweetpotato weevil
Eusimulium pecuarum (Riley) ..... southern buffalo gnat
Eutettix tenellus (Bak.) ..... beet leafhopper
Euxoa messoria (Harr.) ..... dark-sided cutworm
Euxoa ochrogaster (Guen.) ..... red-backed cutworm
Euxoa scandens (Riley) ..... white cutworm
Euxoa tessellata (Harr.) ..... striped cutworm
Evergestis rimosalis (Guen.) ..... cross-striped cabbage worm
Evoxysoma vitis (Saund.) ..... grape seed chalcid
Exartema permundanum Clem. ..... raspberry leaf roller

Fannia canicularis L. ..... little housefly
Fannia scalaris (F.) ..... latrine fly
Felicola subrostrata (Nitz.) ..... cat louse
Feltia annexa (Treit.) ..... granulate cutworm
Feltia malefida (Guen.) ..... pale-sided cutworm
Feltia subgothica (Haw.) ..... dingy cutworm
Fenusa dohrnii (Tischbein) ..... European alder leaf miner
Fidia viticida Walsh ..... grape rootworm
Forficula auricularia L. ..... European earwig
Formica fusca subsericea Say ..... silky ant
Frankliniella fusca (Hinds) ..... tobacco thrips
Frankliniella tritici (Fitch) ..... flower thrips
Fundella cistipennis (Dyar) ..... Caribbean pod borer

Galeruca externa Say ..... peppergrass beetle
Galerucella cavicollis (Lec.) ..... cherry leaf beetle
Galerucella xanthomelaena (Schr.) ..... elm leaf beetle
Galleria mellonella (L.) ..... wax moth
Gargaphia solani Heid. ..... eggplant lacebug
Gastrophilus haemorrhoidalis (L.) ..... nose botfly
Gastrophilus intestinalis Deg. ..... horse botfly
Gastrophilus nasalis (L.) ..... throat botfly
Gelastocoris oculatus (F.) ..... toadbug
Glycobius speciosus (Say) ..... sugar maple borer
Gnorimoschema glochinella (Zell.) ..... eggplant leaf miner
Gnorimoschema lycopersicella (Busck) ..... tomato pinworm
Gnorimoschema operculella (Zell.) ..... potato tuber worm
Goniocotes bidentatus Scop. ..... small pigeon louse
Goniocotes gigas Tasch. ..... large chicken louse
Goniocotes hologaster Nitz. ..... fluff louse
Goniodes dissimilis Nitz. ..... brown chicken louse
Goniodes meleagridis (L.) ..... large turkey louse
Goniurus proteus (L.) ..... bean leaf roller
Gossyparia spuria (Mod.) ..... European elm scale
Gracilaria cuculipennella Hbn. ..... privet leaf miner
Gracilaria negundella Chamb. ..... boxelder leaf roller
Gracilaria syringella F. ..... lilac leaf miner
Grapholitha interstinctana (Clem.) ..... clover head caterpillar
Grapholitha molesta (Busck) ..... oriental fruit moth
Grapholitha packardi Zell. ..... cherry fruitworm
Grapholitha prunivora (Walsh) ..... lesser apple worm
Graptolitha antennata (Walk.) ..... green fruitworm
Gretchena bolliana (Sling.) ..... pecan budmoth
Gryllotalpa hexadactyla Perty ..... northern mole cricket
Gryllus assimilis F. ..... field cricket
Gryllus domesticus L. ..... house cricket
Gynaikothrips uzeli (Zimm.) ..... Cuban laurel thrips

Haemaphysalis cinnabarina Koch ..... bird tick
Haemaphysalis leporis-palustris Pack. ..... rabbit tick
Haematobia irritans L. ..... horn fly
Haematopinus asini (L.) ..... sucking horse louse
Haematopinus eurysternus Nitz. ..... short-nosed cattle louse
Haematopinus suis (L.) ..... hog louse
Haematosiphon inodorus (Duges) ..... poultry bug
Haemodipsus ventricosus Denny ..... rabbit louse
Halisidota caryae (Harr.) ..... hickory tussock moth
Halisidota maculata (Harr.) ..... spotted tussock moth
Halisidota tessellaris (S. & A.) ..... pale tussock moth
Halticus citri (Ashm.) ..... garden flea hopper
Hamadryas antiopa (L.) ..... mourning-cloak butterfly
Hammoderus tessellatus (Hald.) ..... oak sapling borer
Harmolita grandis (Riley) ..... wheat straw worm

Harmolita tritici (Fitch) . . . wheat jointworm
Harrisina americana (Guér.) . . . grape leaf skeletonizer
Harrisina brillians B. & McD. . . . western grape skeletonizer
Heliothis obsoleta (F.) . . . bollworm, corn ear worm
Heliothis virescens (F.) . . . tobacco budworm
Heliothrips fasciatus Perg. . . . bean thrips
Heliothrips haemorrhoidalis (Bouché) . . . greenhouse thrips
Hellula undalis (F.) . . . cabbage webworm
Hemerocampa leucostigma (S. & A.) . . . white-marked tussock moth
Hemerocampa pseudotsugata McD. . . . Douglas fir tussock moth
Hemerocampa vetusta (Bdv.) . . . western tussock moth
Hemerophila pariana (Clerck) . . . apple and thorn skeletonizer
Hemichionaspis aspidistrae (Sign.) . . . fern scale
Hemileuca maia (Drury) . . . buck moth
Hemileuca oliviae Ckll. . . . range caterpillar
Herse cingulata (F.) . . . sweetpotato hornworm
Heterocampa guttivitta (Walk.) . . . saddled prominent
Heteroderes laurentii (Guér.) . . . Gulf wireworm
Hippelates spp. . . . eye gnats
Hippodamia convergens Guer. . . . convergent ladybeetle
Horistonotus uhlerii Horn . . . sand wireworm
Howardia biclavis (Comst.) . . . mining scale
Hyalopterus arundinis (F.) . . . mealy plum aphid
Hydroecia micacea (Esp.) . . . potato stem borer
Hylastinus obscurus (Marsham) . . . clover root borer
Hylecoetus lugubris Say . . . sapwood timber worm
Hylemyia antiqua Meig. . . . onion maggot
Hylemyia brassicae (Bouché) . . . cabbage maggot
Hylemyia cilicrura Rond. . . . seed-corn maggot
Hylobius pales (Hbst.) . . . pales weevil
Hylurgopinus rufipes (Eich.) . . . native elm bark beetle
Hymenia fascialis (Cram.) . . . Hawaiian beet webworm
Hymenia perspectalis (Hbn.) . . . spotted beet webworm
Hypena humuli (Harr.) . . . hop looper
Hypera nigrirostris (F.) . . . lesser clover leaf weevil
Hypera postica (Gyll.) . . . alfalfa weevil
Hypera punctata (F.) . . . clover leaf weevil
Hypermallus villosus (F.) . . . twig pruner
Hyphantria cunea (Drury) . . . fall webworm
Hypoderma bovis Deg. . . . northern cattle grub
Hypoderma lineatum (DeVill.) . . . common cattle grub
Hyponomeuta malinellus Zell. . . . ermine moth
Hypothenemus hispidulus (Lec.) . . . apple twig beetle
Hypsopygia costalis (F.) . . . clover hay worm
Hysteroneura setariae (Thos.) . . . rusty plum aphid

Icerya purchasi Mask. . . . cottony-cushion scale
Illinoia pisi (Kltb.) . . . pea aphid
Illinoia solanifolii (Ashm.) . . . potato aphid
Iridomyrmex humilis Mayr . . . Argentine ant
Ischnaspis longirostris (Sign.) . . . black thread scale
Isia isabella (S. & A.) . . . banded woolly bear
Itame ribearia (Fitch) . . . currant spanworm
Ithycerus noveboracensis (Forst.) . . . New York weevil
Itonida catalpae Comst. . . . catalpa midge
Ixodes ricinus (L.) . . . castor-bean tick
Ixodes ricinus scapularis Say . . . black-legged tick

Janus integer (Nort.) . . . currant stem girdler
Jonthonota nigripes (Oliv.) . . . black-legged tortoise beetle

Kakimia houghtonensis (Troop) . . . gooseberry witch-broom aphid
Kaliosysphinga ulmi (Sund.) . . . elm leaf miner

Laemophloeus minutus Oliv. — flat grain beetle
Languria mozardi Latr. — clover stem borer
Laphygma exigua (Hbn.) — beet armyworm
Laphygma frugiperda (S. & A.) — fall armyworm
Lasioderma sericorne (F.) — cigarette beetle
Lasius niger americanus Emery — cornfield ant
Laspeyresia caryana (Fitch) — hickory shuck worm
Laspeyresia nigricana (Steph.) — pea moth
Latrodectus mactans F. — black widow spider
Lecanium cerasorum Ckll. — calico scale
Lecanium corni Bouché — European fruit lecanium
Lecanium nigrofasciatum Perg. — terrapin scale
Lecanium persicae (F.) — European peach scale
Lecanium prunastri (Boyer) — globose scale
Lema trilineata (Oliv.) — three-lined potato beetle
Lepidosaphes beckii (Newm.) — purple scale
Lepidosaphes ficus (Sign.) — fig scale
Lepidosaphes gloverii (Pack.) — Glover's scale
Lepidosaphes ulmi (L.) — oystershell scale
Lepisma saccharina L. — silverfish
Leptinotarsa decemlineata (Say) — Colorado potato beetle
Leptinotarsa juncta (Germ.) — false potato beetle
Leptocoris trivittatus (Say) — boxelder bug
Leptoglossus phyllopus (L.) — leaf-footed bug
Lethocerus americanus (Leidy) — giant water bug
Ligyrus gibbosus (Deg.) — carrot beetle
Limonius californicus (Mann.) — sugar-beet wireworm
Limonius canus Lec. — Pacific coast wireworm
Limonius ectypus (Say) — eastern field wireworm
Limonius infuscatus Mots. — western field wireworm
Limonius subauratus Lec. — Columbia Basin wireworm
Lipeurus heterographus Nitz. — chicken head louse
Liponyssus bacoti (Hirst.) — tropical rat mite
Lissorhoptrus simplex (Say) — rice water weevil
Listroderes obliquus Klug — vegetable weevil
Listronotus latiusculus (Boh.) — carrot weevil
Lixus concavus Say — rhubarb curculio
Loxostege commixtalis (Walk.) — alfalfa webworm
Loxostege similalis (Guen.) — garden webworm
Loxostege sticticalis (L.) — beet webworm
Lucanus elaphus F. — giant stag beetle
Lucilia spp. — greenbottle flies
Ludius aereipennis (Kby.) — prairie grain wireworm
Ludius inflatus (Say) — dry-land wireworm
Ludius pruininus noxius (Hyslop) — Great Basin wireworm
Ludius suckleyi (Lec.) — Puget Sound wireworm
Luperodes brunneus Crotch — corn silk beetle
Lycophotia margaritosa saucia Hbn. — variegated cutworm
Lygaeonematus erichsonii (Htg.) — larch sawfly
Lygidea mendax Reut. — apple redbug
Lygus communis Knight — pear plant bug
Lygus pratensis (L.) — tarnished plant bug
Lytta nuttalli Say — Nuttal's blister beetle
Lytta vesicatoria (L.) — Spanish fly

Macrobasis unicolor (Kby.) — ash-gray blister beetle
Macrodactylus subspinosus (F.) — rose chafer
Macronoctua onusta Grote — iris borer
Macrosiphoniella sanborni (Gill.) — chrysanthemum aphid
Macrosiphum granarium (Kby.) — English grain aphid
Macrosiphum rosae (L.) — rose aphid
Macrosiphum rudbeckiae (Fitch) — goldenglow aphid

Magdalis armicollis (Say) ..... red elm bark weevil
Magdalis barbita (Say) ..... black elm bark weevil
Magicicada septendecim (L.) ..... periodical cicada
Malacosoma americana (F.) ..... eastern tent caterpillar
Malacosoma californica (Pack.) ..... California tent caterpillar
Malacosoma disstria Hbn. ..... forest tent caterpillar
Malacosoma pluvialis (Dyar) ..... western tent caterpillar
Mamestra picta Harr. ..... zebra caterpillar
Mancasellus brachyrus Harger ..... watercress sowbug
Marmara elotella Busck ..... apple bark miner
Marmara pomonella Busck ..... apple fruit miner
Megalopyge opercularis (S. & A.) ..... puss caterpillar
Melanocallis caryaefoliae (Davis) ..... black pecan aphid
Melanophila consputa Lec. ..... charcoal beetle
Melanophila fulvoguttata (Harr.) ..... hemlock borer
Melanophila fulvoguttata drummondi (Kby.) ..... fir flatheaded borer
Melanoplus bivittatus (Say) ..... two-striped grasshopper
Melanoplus devastator Scudd. ..... devastating grasshopper
Melanoplus differentialis (Thos.) ..... differential grasshopper
Melanoplus femur-rubrum (Deg.) ..... red-legged grasshopper
Melanoplus mexicanus spretus (Walsh) ..... Rocky Mountain grasshopper
Melanotus oregonensis (Lec.) ..... Oregon wireworm
Melittia satyriniformis Hbn. ..... squash borer
Melittomma sericeum Harr. ..... chestnut timber worm
Melophagus ovinus (L.) ..... sheep tick
Merodon equestris (F.) ..... narcissus bulb fly
Meromyza americana Fitch ..... wheat stem maggot
Metamasius hemipterus (L.) ..... West Indian cane weevil
Metamasius ritchiei Marshall ..... pineapple weevil
Metamasius sericeus (Oliv.) ..... silky cane weevil
Metriona bicolor (F.) ..... golden tortoise beetle
Microcentrum retinerve (Burm.) ..... angular-winged katydid
Micromyzus violae (Perg.) ..... violet aphid
Micronematus californicus (Marlatt) ..... California pear slug
Mindarus abietinus (Koch) ..... balsam twig aphid
Mineola indigenella (Zell.) ..... leaf crumpler
Mineola vaccinii (Riley) ..... cranberry fruitworm
Miris dolabratus (L.) ..... meadow plant bug
Monarthropalpus buxi Laboulb. ..... boxwood leaf miner
Monochamus maculosus Hald. ..... spotted pine sawyer
Monochamus marmorator Kby. ..... balsam fir sawyer
Monochamus notatus (Drury) ..... northeastern sawyer
Monochamus oregonensis Lec. ..... Oregon fir sawyer
Monochamus scutellatus (Say) ..... white-spotted sawyer
Monochamus titillator (F.) ..... southern pine sawyer
Monomorium minimum (Buckl.) ..... little black ant
Monomorium pharaonis (L.) ..... Pharaoh's ant
Monophadnoides rubi (Harr.) ..... raspberry sawfly
Monoptilota pergratialis (Hulst) ..... lima bean vine borer
Monoxia puncticollis (Say) ..... beet leaf beetle
Mordwilkoja vagabunda (Walsh) ..... poplar vagabond aphid
Murgantia histrionica (Hahn) ..... harlequin bug
Musca domestica L. ..... housefly
Musca vicina Macq. ..... oriental housefly
Muscina stabulans Fall. ..... false stablefly
Myelois venipars Dyar ..... navel orange worm
Myzocallis kahawaluokalani Kirk. ..... crapemyrtle aphid
Myzus cerasi (F.) ..... black cherry aphid
Myzus persicae (Sulz.) ..... green peach aphid

Necrobia ruficollis (F.) ..... red-shouldered ham beetle
Necrobia rufipes (Deg.) ..... red-legged ham beetle

Neleucania albilinea (Hbn.) ..... wheat head armyworm
Neoclytus acuminatus (F.) ..... red-headed ash borer
Neodiprion abietis (Harr.) ..... spruce sawfly
Neodiprion burkei Midd. ..... lodgepole sawfly
Neodiprion lecontei (Fitch) ..... red-headed pine sawfly
Neodiprion tsugae Midd. ..... hemlock sawfly
Neolecanium cornuparvum (Thro) ..... magnolia scale
Neophasia menapia (Feld.) ..... pine butterfly
Nephelodes emmedonia (Cram.) ..... bronzed cutworm
Nephopteryx rubrizonella Rag. ..... pear fruit borer
Nezara viridula (L.) ..... southern green stinkbug
Niptus hololeucus Fald. ..... golden spider beetle
Nodonota puncticollis (Say) ..... rose leaf beetle
Nomius pygmaeus (Dej.) ..... stink beetle
Nosopsyllus fasciatus (Bosc.) ..... rat flea
Notolophus antiqua (L.) ..... rusty tussock moth
Nygmia phaeorrhoea (Donov.) ..... brown-tail moth
Nysius ericae (Schill.) ..... false chinch bug

Oberea bimaculata (Oliv.) ..... raspberry cane borer
Oecanthus nigricornis Walk. ..... black-horned tree cricket
Oecanthus nigricornis quadripunctatus Beut. ..... four-spotted tree cricket
Oecanthus niveus (Deg.) ..... snowy tree cricket
Oeciacus vicarius Horv. ..... swallow bug
Oestris ovis L. ..... sheep botfly
Olethreutes illepida (Butl.) ..... koa seed worm
Olethreutes variegana (Hbn.) ..... green budworm
Omiodes accepta (Butl.) ..... sugarcane leaf roller
Omiodes blackburni (Butl.) ..... coconut leaf roller
Omphisa anastomosalis (Guen.) ..... sweetpotato vine borer
Oncideres cingulatus (Say) ..... twig girdler
Orchestes pallicornis Say ..... apple flea weevil
Orcus chalybeus (Bdv.) ..... steel-blue ladybeetle
Ornithodoros megnini Duges ..... ear tick
Orthezia insignis Dougl. ..... greenhouse orthezia
Oryzaephilus surinamensis (L.) ..... saw-toothed grain beetle
Oscinella frit L. ..... frit fly
Oxyptilus periscelidactylus (Fitch) ..... grape plume moth

Pachynematus ocreatus Hgtn. ..... yellow-headed spruce sawfly
Pachypsylla celtidis-mamma Riley ..... hackberry nipple gall
Pachyzancla bipunctalis (F.) ..... southern beet webworm
Paleacrita vernata (Peck.) ..... spring cankerworm
Panchlora cubensis Sauss. ..... Cuban cockroach
Pantomorus godmani (Crotch) ..... Fuller's rose beetle
Papaipema nebris nitela (Guen.) ..... stalk borer
Papaipema purpurifascia (G. & R.) ..... columbine borer
Papilio glaucus turnus L. ..... tiger swallowtail
Papilio polyxenes F. ..... black swallowtail, celery worm, parsley worm
Papilio thoas L. ..... orange dog
Paraclemensia acerifoliella (Fitch) ..... maple leaf cutter
Paranthrene polistiformis (Harr.) ..... grape root borer
Paratetranychus citri McG. ..... citrus red mite
Paratetranychus heteronychus Ewing ..... date mite
Paratetranychus pilosus (G. & F.) ..... European red mite
Paratetranychus yothersi McG. ..... avocado red mite
Parlatoria blanchardii (Targ.) ..... parlatoria date scale
Parlatoria pergandii Comst. ..... chaff scale
Passalus cornutus F. ..... horned passalus
Pectinophora gossypiella (Saund.) ..... pink bollworm
Pediculoides ventricosus Newp. ..... straw itch mite
Pediculus humanus corporis Deg. ..... body louse

Pediculus humanus humanus L. ..... head louse
Pegomyia hyoscyami Panz. ..... spinach leaf miner
Pegomyia rubivora (Coq.) ..... raspberry cane maggot
Pemphigus betae Doane ..... sugar-beet root aphid
Peranabrus scabricollis (Thos.) ..... coulee cricket
Periphyllus lyropictus (Kess.) ..... Norway maple aphid
Periphyllus negundinis (Thos.) ..... boxelder aphid
Periplaneta americana (L.) ..... American cockroach
Periplaneta australasiae (F.) ..... Australian cockroach
Perkinsiella saccharicida Kirk. ..... sugarcane leafhopper
Peronea minuta (Rob.) ..... yellow-headed fireworm
Peronea variana (Fern.) ..... black-headed budworm
Petrova comstockiana (Fern.) ..... pitch twig moth
Phaedon aeruginosus Suffr. ..... watercress leaf beetle
Phalacrus politus Melsh. ..... smut beetle
Phenacoccus gossypii Towns. & Ckll. ..... Mexican mealybug
Philaenus lineatus (L.) ..... lined spittle bug
Phlyctaenia rubigalis (Guen.) ..... greenhouse leaf tyer
Phobetron pithecium (S. & A.) ..... hag moth
Phoenicococcus marlatti Ckll. ..... red date scale
Pholus achemon (Drury) ..... achemon sphinx
Phorodon humuli (Schr.) ..... hop aphid
Phryganidia californica Pack. ..... California oak worm
Phthirus pubis (L.) ..... crab louse
Phthorophloeus limnaris (Harr.) ..... peach bark beetle
Phyllocoptes oleivorus Ashm. ..... citrus rust mite
Phyllotreta armoraciae (Koch) ..... horseradish flea beetle
Phyllotreta pusilla Horn ..... western black flea beetle
Phyllotreta ramosa (Crotch) ..... western striped flea beetle
Phyllotreta vittata (F.) ..... striped flea beetle
Phylloxera devastatrix Perg. ..... pecan phylloxera
Phylloxera vitifoliae Fitch ..... grape phylloxera
Phytomyza aquilegiae (Hardy) ..... columbine leaf miner
Phytomyza chrysanthemi (Kowarz) ..... chrysanthemum leaf miner
Phytomyza delphiniae Frost ..... larkspur leaf miner
Phytomyza ilicicola Loew ..... holly leaf miner
Phytophaga destructor (Say) ..... hessian fly
Pilocrocis tripunctata (F.) ..... sweetpotato leaf roller
Pineus strobi Htg. ..... pine bark aphid
Piophila casei L. ..... cheese skipper
Pissodes engelmanni Hopk. ..... Engelmann spruce weevil
Pissodes nemorensis Germ. ..... deodar weevil
Pissodes radiatae Hopk. ..... Monterey pine weevil
Pissodes sitchensis Hopk. ..... Sitka spruce weevil
Pissodes strobi (Peck) ..... white-pine weevil
Pissodes yosemite Hopk. ..... Yosemite bark weevil
Plathypena scabra (F.) ..... green clover worm
Platyptilia carduidactyla (Riley) ..... artichoke plume moth
Platyptilia pusillodactyla (Walk.) ..... lantana plume moth
Platysamia cecropia (L.) ..... cecropia moth
Platysystrophus minutus (Drury) ..... oak timber worm
Plodia interpunctella (Hbn.) ..... Indian-meal moth
Plutella maculipennis (Curt.) ..... diamondback moth
Podisus maculiventris (Say) ..... spined soldier bug
Podosesia fraxini (Lugger) ..... ash borer
Podosesia syringae (Harr.) ..... lilac borer
Poecilocapsus lineatus (F.) ..... four-lined plant bug
Pogonomyrmex badius (Latr.) ..... Florida harvester ant
Pogonomyrmex barbatus (F. Smith) ..... red harvester ant
Pogonomyrmex californicus (Buckl.) ..... California harvester ant
Polia legitima (Grote) ..... striped garden caterpillar
Polia renigera (Steph.) ..... bristly cutworm

Pollenia rudis (F.) ..... cluster fly
Polychrosis viteana (Clem.) ..... grape berry moth
Polyphylla decemlineata (Say) ..... ten-lined June beetle
Pomphopoea sayi Lec. ..... Say's blister beetle
Popillia japonica Newm. ..... Japanese beetle
Porosagrotis orthogonia (Morr.) ..... pale western cutworm
Porthetria dispar (L.) ..... gypsy moth
Prenolepis longicornis (Latr.) ..... crazy ant
Prionoxystus macmurtrei (Guér.) ..... little carpenter worm
Prionoxystus robiniae (Peck) ..... carpenter worm
Prionus californicus Mots. ..... California prionus
Prionus laticollis (Drury) ..... broad-necked root borer
Prociphilus imbricator (Fitch) ..... beech blight aphid
Prociphilus tessellatus (Fitch) ..... woolly alder aphid
Prodenia eridania (Cram.) ..... southern armyworm
Prodenia ornithogalli Guen. ..... yellow-striped armyworm
Proteoteras willingana (Kearf.) ..... boxelder twig borer
Protoparce quinquemaculata (Haw.) ..... tobacco worm
Protoparce sexta (Johan.) ..... tomato worm
Protopulvinaria pyriformis Ckll. ..... pyriform scale
Psallus seriatus (Reut.) ..... cotton flea hopper
Pseudoanidea duplex (Ckll.) ..... camphor scale
Pseudococcus adonidum (L.) ..... long-tailed mealybug
Pseudococcus brevipes (Ckll.) ..... pineapple mealybug
Pseudococcus citri (Risso) ..... citrus mealybug
Pseudococcus gahani Green ..... citrophilus mealybug
Pseudococcus maritimus (Ehrh.) ..... grape mealybug
Pseudococcus nipae (Mask.) ..... coconut mealybug
Pseudolynchia maura (Bigot) ..... pigeon fly
Psila rosae (F.) ..... carrot rust fly
Psoroptes communis Feurst. ..... scab mite
Psoroptes ovis Her. ..... sheep scab mite
Psorosina hammondi (Riley) ..... apple leaf skeletonizer
Psyllia buxi (L.) ..... boxwood psyllid
Psyllia mali (Schmidt) ..... apple sucker
Psyllia pyricola (Foerst.) ..... pear psylla
Psylliodes punctulata Melsh. ..... hop flea beetle
Pteronidea ribesii (Scop.) ..... imported currant worm
Pteronidea ventralis (Say) ..... willow sawfly
Ptinus brunneus Dufts. ..... brown spider beetle
Ptinus fur L. ..... white-marked spider beetle
Ptinus villiger (Riet.) ..... hairy spider beetle
Pulex irritans L. ..... human flea
Pulvinaria amygdali Ckll. ..... cottony peach scale
Pulvinaria psidii Mask. ..... green shield scale
Pulvinaria vitis (L.) ..... cottony maple scale
Pycnoscelus surinamensis (L.) ..... Surinam roach
Pyralis farinalis L. ..... meal moth
Pyrausta ainsliei Heinr. ..... smartweed borer
Pyrausta nubilalis (Hbn.) ..... European corn borer

Rachela bruceata (Hulst) ..... Bruce's spanworm
Recurvaria milleri Busck ..... lodgepole needle miner
Recurvaria nanella (Hbn.) ..... lesser budmoth
Reduvius personatus (L.) ..... masked hunter
Rhabdocnemis obscura (Bdv.) ..... New Guinea sugarcane weevil
Rhabdopterus picipes (Oliv.) ..... cranberry root worm
Rhagoletis cingulata (Loew) ..... cherry fruitfly, cherry maggot
Rhagoletis completa Cress. ..... walnut husk fly
Rhagoletis fausta O. S. ..... black cherry fruitfly
Rhagoletis pomonella (Walsh) ..... apple maggot, blueberry maggot
Rhipicephalus sanguinius Latr. ..... brown dog tick

Rhizobius ventralis (Er.) ..... black ladybeetle
Rhizoecus terrestris (Newst.) ..... ground mealybug
Rhizoglyphus hyacinthi Bdv. ..... bulb mite
Rhodites radicum O. S. ..... rose root gall
Rhodites rosae (L.) ..... mossy rose gall
Rhopalosiphum prunifoliae (Fitch) ..... apple grain aphid
Rhopalosiphum pseudobrassicae (Davis) ..... turnip aphid
Rhopobota naevana (Hbn.) ..... black-headed fireworm
Rhyacionia buoliana (Schiff.) ..... European pine shoot moth
Rhynchites bicolor (F.) ..... rose curculio
Rodolia cardinalis (Muls.) ..... vedalia
Romalea microptera (Beauv.) ..... eastern lubber grasshopper

Saissetia hemisphaerica (Targ.) ..... hemispherical scale
Saissetia oleae (Bern.) ..... black scale
Saperda calcarata Say ..... poplar borer
Saperda candida F. ..... roundheaded apple tree borer
Saperda tridentata Oliv. ..... elm borer
Saperda vestita Say ..... linden borer
Sarcophaga kellyi Ald. ..... grasshopper maggot
Sarcophaga spp. ..... flesh flies
Sarcoptes scabiei Deg. ..... itch mite
Scapteriscus acletus R. & H. ..... southern mole cricket
Scapteriscus vicinus Scudd. ..... changa
Schistocerca americana (Drury) ..... American grasshopper
Schistoceros hamatus (F.) ..... apple twig borer
Schizura concinna (S. & A.) ..... red-humped caterpillar
Schizura unicornis (S. & A.) ..... unicorn caterpillar
Scirtothrips citri (Moult.) ..... citrus thrips
Scobicia declivis (Lec.) ..... lead cable borer
Scolytus multistriatus Marsham ..... smaller European elm bark beetle
Scolytus muticus Say ..... hackberry engraver
Scolytus quadrispinosus Say ..... hickory bark beetle
Scolytus rugulosus Ratz. ..... shot-hole borer
Scolytus unispinosus Lec. ..... Douglas fir engraver
Scolytus ventralis Lec. ..... fir engraver
Scotogramma trifolii (Rott.) ..... clover cutworm
Scudderia furcata Brunner ..... fork-tailed bush katydid
Scutigera forceps Raf. ..... house centipede
Scutigerella immaculata (Newp.) ..... garden centipede
Selenothrips rubrocinctus (Giard) ..... red-banded thrips
Septis arctica (Bdv.) ..... yellow-headed cutworm
Sibine stimulea (Clem.) ..... saddleback caterpillar
Sidemia devastatrix (Brace) ..... glassy cutworm
Silvanus gemellatus Duv. ..... square-necked grain beetle
Simulium meridionale Riley ..... turkey gnat
Sitona hispidula (F.) ..... clover root curculio
Sitophilus granarius (L.) ..... granary weevil
Sitophilus oryzae (L.) ..... rice weevil
Sitotroga cerealella (Oliv.) ..... angoumois grain moth
Solenopsis geminata (F.) ..... fire ant
Solenopsis molesta (Say) ..... thief ant
Sphinx lineata F. ..... white-lined sphinx
Spilonota ocellana (D. & S.) ..... eye-spotted budmoth
Spodoptera mauritia (Bdv.) ..... nutgrass armyworm
Stagmomantis carolina (Johan.) ..... Carolina mantis
Stegobium paniceum (L.) ..... drug store weevil
Stenoplematus fuscus Hald. ..... Jerusalem cricket
Stephanitis rhododendri Horv. ..... rhododendron lacebug
Sternochetus mangiferae (F.) ..... mango weevil
Stictocephala festina (Say) ..... three-cornered alfalfa hopper
Stilpnotia salicis (L.) ..... satin moth

Stomoxys calcitrans (L.) ..... stablefly
Straussia longipennis (Wied.) ..... sunflower maggot
Strymon melinus (Hbn.) ..... cotton-square borer
Synanthedon pictipes (G. & R.) ..... lesser peach borer
Synanthedon rutilans (Hy. Edw.) ..... strawberry crown moth
Synanthedon tipuliformis (L.) ..... currant borer
Systena blanda Melsh. ..... pale-striped flea beetle

Tabanus atratus F. ..... black horsefly
Tabanus lineola F. ..... striped horsefly
Tachycines asynamorus Adel. ..... greenhouse stone cricket
Tachyterellus quadrigibbus (Say) ..... apple curculio
Taeniothrips inconsequens (Uzel) ..... pear thrips
Taeniothrips simplex Morison ..... gladiolus thrips
Tapinoma sessile (Say) ..... odorous house ant
Tarsonemus approximatus narcissi Ewing ..... bulb-scale mite
Tarsonemus latus Banks ..... broad mite
Tarsonemus pallidus Banks ..... cyclamen mite
Tegeticula yuccasella (Riley) ..... yucca moth
Telea polyphemus (Cram.) ..... polyphemus moth
Teleonemia lantanae Dist. ..... lantana leaf bug
Tenebrio molitor L. ..... yellow mealworm
Tenebrio obscurus F. ..... dark mealworm
Tenebroides mauritanicus (L.) ..... cadelle
Tenodera sinensis Sauss. ..... Chinese mantis
Tetraleurodes mori Quaint. ..... mulberry whitefly
Tetramorium caespitum (L.) ..... pavement ant
Tetranychus sexmaculatus Riley ..... six-spotted mite
Tetranychus telarius (L.) ..... common red spider
Tetraopes tetrophthalmus (Forst.) ..... red milkweed beetle
Tetropium abietis Fall ..... roundheaded fir borer
Thamnotettix clitellarius (Say) ..... saddled leafhopper
Thermobia domestica Pack. ..... firebrat
Thrips tabaci Lind. ..... onion thrips
Thyridopteryx ephemeraeformis (Haw.) ..... bagworm
Tinea granella L. ..... European grain moth
Tinea pellionella L. ..... casebearing clothes moth
Tineola biselliella (Hum.) ..... webbing clothes moth
Tipula simplex Doane ..... range crane fly
Tischeria malifoliella Clem. ..... apple leaf trumpet miner
Toumeyella liriodendri (Gmel.) ..... tuliptree scale
Toxoptera aurantiae Boyer ..... black citrus aphid
Toxoptera graminum Rond. ..... green bug
Toxotrypana curvicauda Gerst. ..... papaya fruitfly
Trachelus tabidus (F.) ..... black grain stem sawfly
Trachykele blondeli Marseul ..... western cedar borer
Tremex columba (L.) ..... pigeon tremex
Trialeurodes floridensis (Quaint.) ..... avocado whitefly
Trialeurodes packardi (Morrill) ..... strawberry whitefly
Trialeurodes vaporariorum (Westw.) ..... greenhouse whitefly
Trialeurodes vittatus (Quaint.) ..... grape whitefly
Triatoma sanguisuga (Lec.) ..... bloodsucking conenose
Tribolium castaneum (Hbst.) ..... red flour beetle
Tribolium confusum Duv. ..... confused flour beetle
Tribolium spp. ..... flour beetles
Trichobaris trinotata (Say) ..... potato stalk borer
Trichodectes equi (L.) ..... horse biting-louse
Trichophaga tapetzella (L.) ..... carpet moth
Trinoton querquedulae (L.) ..... large duck louse
Trioza diospyri (Ashm.) ..... persimmon psylla
Troctes divinatorius (Müll.) ..... booklouse
Trombicula irritans (Riley) ..... chigger

Tropaea luna (L.) ..... luna moth
Tunga penetrans (L.) ..... chigoe
Tychius griseus Schaeffer ..... clover head weevil
Tyloderma fragariae (Riley) ..... strawberry crown borer
Typhlocyba pomaria McAtee ..... white apple leafhopper
Typhlocyba rosae (L.) ..... rose leafhopper

Vespa crabro L. ..... giant hornet
Vespamima sequoiae (Hy. Edw.) ..... Sequoia pitch moth
Vespula maculata (L.) ..... bald-faced hornet
Vitula serratilineella Rag. ..... dried fruit moth

Winthemia quadripustulata (F.) ..... red-tailed tachina
Wyeomyia smithii (Coq.) ..... pitcherplant mosquito

Xenopsylla cheopis (Rothsch.) ..... oriental rat flea
Xylocopa virginica (Drury) ..... carpenter bee
Xylothechus aceris Fisher ..... gall-making maple borer

Zeuzera pyrina (L.) ..... leopard moth
Zophodia grossulariae (Riley) ..... gooseberry fruitworm
Zygogramma exclamationis (F.) ..... sunflower beetle

Scientific Notes

Oxygen as a Factor in Vacuum Fumigation.—In 1932 the senior author (Cotton 1932) made a report on the effect of oxygen deficiency on the susceptibility of insects to fumigants. He concluded that in vacuum fumigation as the pressure was reduced and the oxygen content of the fumigation chamber correspondingly reduced, the susceptibility of an insect to a fumigant increased. That this increase in susceptibility to fumigants is due to oxygen deficiency and not to the difference in pressure has been confirmed by recent experimental work.

In an unloaded vacuum fumigation vault of 357.5 cubic feet capacity it was determined that with an absolute pressure of 2½ inches and an air temperature of 64° F a dosage of 10 pounds of a 9:1 mixture of ethylene oxide and carbon dioxide per 1000 cubic feet gave a 100 per cent kill of adults of the flour beetle *Tribolium confusum*, with an exposure of one hour. A test was then conducted in the same vault at the same pressure but with a different oxygen content. The air was pumped from the vault until an absolute pressure of one-half inch was obtained. Pure oxygen was then introduced into the tank until an absolute pressure of 2½ inches was obtained. Under these initial conditions exposure for one hour to the same dosage of 10 pounds of a 9:1 mixture of ethylene oxide and carbon dioxide per 1000 cubic feet of space at a temperature of 67° F gave no kill of adult flour beetles.

In both experiments the absolute pressure, the quantity of fumigant and the length of exposure were the same. In the first experiment the oxygen content of the vault was reduced from the normal 21 per cent to 1.77 per cent while in the second test the oxygen content was 7.26 per cent. The calculations of the oxygen content of the vault in the two tests were based on a barometric pressure of 29.7 inches which obtained during the first test and 29 inches during the second test. In the first experiment a slightly larger quantity of nitrogen was necessarily present in the vault, but since this gas is inert this factor would have no influence on results.

It is evident, therefore, that from a physiological standpoint the reduction in the oxygen content of the vault in vacuum fumigation is the factor that increases the susceptibility of an insect to certain fumigants rather than the reduction in pressure, although in a loaded vault the decrease in pressure naturally adds to the efficiency of a fumigant by increasing penetration.

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R. T. Cotton, George B. Wagner and H. D. Young, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*—4-12-37.

Greatly Increased Yields of Peanuts Obtained in Attempts to Control Potato Leafhopper.—Results of preliminary tests during 1932 and 1933 on control of the potato leafhopper, *Empoasca fabae* (Harris), on peanuts at Arlington Experiment Farm, Arlington, Va., by the use of Bordeaux mixture (4:4:50) were reported by Poos in 1934. The increase in yield (green weight of entire plants a short time before killing frost) obtained from the sprayed areas during these two seasons averaged 21 per cent greater than the yield from the unsprayed areas. Accordingly, further preliminary tests were made during 1934 in the Virginia–North Carolina peanut section at the Holland Branch of the Virginia Agricultural Experiment Station. Bordeaux mixture was sprayed on five one fortieth-acre plots on July 11, August 4 and August 20, and the increase in the yields of field-cured peanuts from these plots (maintained to observe the effect on the crop of various kinds and amounts of lime applied to the soil) ranged from 60 to 73.9 per cent more than from identical unsprayed plots. During 1935 further tests were made, using a variety of materials including sulfur and two copper compounds in addition to Bordeaux mixture. The number of applications of Bordeaux and sulfur was varied and all tests were replicated four times. Adequate checks were provided for comparison. Increases in yield were obtained with sulfur as well as with the copper compounds. The average increase in yield of field-cured peanuts from the treated plots, as compared with the untreated, ranged from 19 to 50 per cent. During 1936 this work was further expanded and increases in yields from the treated plots ranged from 30 to 60 per cent. Additional tests, in which three applications of sulfur dust and Bordeaux dust were made, were conducted on peanuts grown on four different types of soil in Nansemond county, Va. Most of the tests conducted in all of this work involved the use of three applications of the materials during the growing season. Shelling tests made from samples of the field-cured peanuts from each plot were conducted each year and indicated no significant differences in the individual weight and number of nut meats in samples from treated plots as compared with those from untreated plots. Another factor of considerable significance, in considering the increased value of the treated crop, is the increase in quality and amount of forage obtained. No attempt has been made to measure this factor although it is undoubtedly important. Of significance, also, is the fact that, at digging time, many more nuts are left in the soil in which treated plants were grown than in soil in which untreated plants were grown, in addition to the increased yields harvested. On account of frost, the treated plants are dug before reaching the ideal stage for digging. These nuts are well utilized by the grower in the production of pork. Further work will be necessary to determine the best number and time of applications of the various materials used and the cost of the treatment before definite recommendations can be made to the growers. It is hoped to continue this work in order to determine these points as early as possible.

From data obtained by making counts of the populations of the potato leafhopper, *Empoasca fabae* (Harris), it is evident that it was not abundant enough to be responsible for all of the losses in yield recorded. It is also evident, however, that this species of leafhopper is responsible for a considerable loss in yield of peanuts in the Virginia–North Carolina area during certain seasons as observed during the period 1931 to 1936, inclusive. The fact that even in fields with low leafhopper populations the treated plants remain green and in a thrifty growing condition until killed by frost, while those untreated usually mature early in October, indicates that some type of plant stimulation is probably involved. Control of diseases, especially leaf spot, is also quite evidently involved. These factors are being investigated by the Division of Horticultural Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.

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F. W. POOS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine,* and E. T. BATTEN, *Superintendent, Holland Branch, Virginia Agricultural Experiment Station, Holland.*—3-15-37.

Zinc Oxide–Zinc Acetate Mixture as a Safener for Arsenical Sprays.—Laboratory studies, in a search for safeners for arsenical sprays, indicate that a mixture of zinc oxide, 4 parts, and zinc acetate, 1 part, added to certain spray combinations or to waters that react with either lead arsenate or calcium arsenate, prevents the formation of water-soluble

arsenic. It was found that when the zinc oxide–zinc acetate mixture was used at the rate of .5 pound to 100 gallons of spray, and was first added to the spray tank of water, followed by the addition of either lead or calcium arsenate, that only a trace of water-soluble arsenic could be detected after reacting periods of one-half hour, one hour, and five hours. Certain spray waters from the Medford, Ore., area that ordinarily react with lead arsenate and cause very severe foliage injury, attained an equilibrium with only a trace of water-soluble arsenic. When various types of calcium arsenate, both commercial products and laboratory prepared basic calcium arsenate and tricalcium arsenate, were added to water which contained soluble sulfates, carbonates and chlorides, varying amounts of water-soluble arsenic were formed, depending usually upon the amount of free calcium hydrate present in the arsenical. When the zinc oxide–zinc acetate mixture was first added to this salt-containing water, followed by the addition of the calcium arsenate, no water-soluble arsenic formed.

Last season zinc oxide was used as a safener for calcium arsenate in codling moth experimental tests, and showed promising results. It was noted especially that the arsenical injury which often occurs in the calyx region of Newtown apples was reduced very materially. When calcium arsenate was used alone, 28.4 per cent calyx injury occurred. Where zinc oxide had been added as a safener, 1.9 per cent injury was recorded. The zinc sulfate–calcium hydrate safener reduced the injury to 9.2 per cent.

Under conditions where severe injury may occur, it is suggested that the zinc oxide–zinc acetate mixture be used at the rate of 1 pound to 100 gallons.

R. H. Robinson and Leroy Childs, *Oregon Agricultural Experiment Station, Corvallis.*—4-9-37.

Effect of Ferric Oxide on Acid Lead Arsenate as a Stomach Poison and Repellent for Japanese Beetle.—During the summer of 1936, at Moorestown, N. J., several cases of arsenical injury to foliage of oak, linden, elm and maple were observed on trees which had been sprayed with acid lead arsenate as a repellent against the Japanese beetle. Ginsburg & Mann (1931) reported that ferric oxide acts as a corrective for arsenical injury when mixed with acid lead arsenate. In order to determine the effect of adding this material

Table 1.—Results of spraying tests of acid lead arsenate, with and without ferric oxide, on the mortality of Japanese beetle and the extent of its feeding.

Pounds Ferric Oxide	Av. No. Beetles Poisoned out of 200	Per Cent Relative Poisoning	Square Inches of Foliage Eaten	Per Cent Relative Feeding
0	80.7±9.26	100±16	2.3±.26	100±16
8	40.1±5.53	50± 9	3.5±.45	152±26
16	50.8±4.93	63± 9	6.3±.77	274±45

on the control of the beetle, smartweed was sprayed with 8 pounds of acid lead arsenate alone and in combination with 8 and 16 pounds of ferric oxide per 100 gallons of water. The effect of these sprays on the beetle was determined under controlled conditions as described by Fleming (1934) and Fleming & Baker (1934). The results are given in table 1.

The data show a significant reduction in mortality and an increase in the amount of feeding which seems to approach significance, following the inclusion of ferric oxide with acid lead arsenate in the spray on smartweed. The results indicate that the use of ferric oxide with lead arsenate for the purpose of reducing arsenical injury to shade trees would be unsatisfactory because it reduces the insecticidal and repellent value of the lead arsenate.

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W. E. Fleming and F. E. Baker, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*—3-24-37.

***Lariophagus distinguendus* Foerst. Parasitic on *Sitodrepa panicea* L. in New York.**—In December 1936 two packages of ice cream powder were purchased in a grocery store in Lockport, N. Y. On examination both packages were found to be infested with the larvae of an anobid beetle. These larvae were tentatively determined as *Sitodrepa panicea* L.

The infested material was placed in a closed container and kept at room temperature. A few days later a chalcid was found in the container and in the first week in January two more appeared. Further examination revealed that many of the beetle larvae had one or occasionally two parasitic larvae clinging to them, presumably the larval stage of the chalcid. After examination this parasitized material was killed and preserved. Apparently the examination was more thorough than was intended as no more adult chalcids appeared.

In February adult beetles were found. These increased in numbers until by the first week in March hundreds of them were crawling over the surface of the powder and on the walls of the container. With the appearance of the adult beetles it was possible to confirm the determination of *Sitodrepa panicea*.

The chalcids were determined by A. B. Gahan as *Lariophagus distinguendus* Foerst., a parasite of several insects infesting stored food products including *Rhizopertha dominica*, *Calandra granaria* and *C. oryzae*. It has also been reared experimentally from the braconid *Habrobracon juglandis* Ashm. *L. distinguendus* has been reared as a parasite of *S. panicea* in Europe, but records of this insect in the United States are from other hosts. *Pteromalus* (*Meraporus*) *calandrae* How., which has been reared from *S. panicea* in the United States, is considered the same as *L. distinguendus* by Gahan (1920), but Waterston (1921) regards them as two distinct species.

The biology, morphology, behavior and taxonomic relationships of *L. distinguendus* have been studied by a number of investigators (Durrant 1921; Goodrich 1921; Hase 1919, 1924; Ruschke 1921; Schulz 1919), mostly European. The work is rather widely scattered through several publications. The more important papers are listed here.

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L. L. Pechuman, *Cornell University, Ithaca, N. Y.*—3-19-37.

New Technic for Hatching Codling Moth Eggs.—In the course of experimental work at the Urbana laboratory various changes have been made in the methods of rearing larvae of the codling moth, *Carpocapsa pomonella* L., for insecticide tests. Farrar & Flint (1930) and Farrar & McGovran (1935) have mentioned and described the methods which have been devised and used for this work. Up to the present no radical changes have been made in these methods, except that the writer has developed a different type of hatching box.

The old type of hatching box consisted of a mailing tube with one or two shell vials .75 by 2.5 inches fitted into the side. Codling moth eggs were deposited on Cellophane which was cut into strips suitable for storage in this type of container. The young larvae upon

hatching were attracted into the glass vials by the light. From these vials they were transferred with a camel's-hair brush to the test fruit.

The new type of hatching box is a round cardboard carton commonly known as a cottage cheese or ice-cream container. The one-half pint size is found to be very efficient for rearing purposes. The can is unaltered except that the cover is discarded and is replaced by the smaller half of a 9 cm. Petri dish which fits snugly over the top. A rubber band is used to hold the glass cover in place. Codling moth eggs are collected on perforated Cellophane in separate oviposition cages. The Cellophane is cut into strips 2 inches wide and each strip into 2-inch squares, which are placed one on top of the other in the carton. Not more than 500 eggs are placed in one box.

The young larvae, upon hatching, either drop through the perforations of the Cellophane to the bottom of the container or crawl horizontally to the sides of the box. In either case, they tend to collect on the white interior surface of the carton and on the glass cover. It is extremely easy to transfer these larvae with a camel's-hair brush to the test fruit. After collecting all of the larvae from the sides of the box and from the glass cover, the box is tipped slightly to dislodge the Cellophane and thus expose the bottom of the box. Many larvae are collected, also, from this area. After the larvae still present on the Cellophane are transferred, the Cellophane squares bearing the unhatched eggs are returned to their original position. Each square is examined separately. Larvae are transferred at four hour intervals from 8 a.m. to 8 p.m.

Some advantages of the new box over the mailing tube are: (1) Since few larvae hatch between 8 p.m. and 8 a.m. nearly all larvae are collected within four hours of the hatching time. The collector goes after the larvae instead of waiting for the larvae to come to him. (2) Only a small percentage of the larvae received are fatigued or injured. Young codling moth larvae are very cannibalistic and come in contact with each other more frequently when confined in a small vial. (3) As the condition of the larvae is more uniform, the tests tend to become more consistent and reliable. (4) The larvae are more easily detected, thus decreasing the time of transferring them to the test fruit. (5) Larvae may be collected at night as well as in the daytime, as light does not play such an important part as in the old method.

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Dwight Powell, *Illinois Natural History Survey* and *Illinois Agricultural Experiment Station, Urbana.*—4-12-37.

Improved Poisoned Bait for Corn Root Webworm Affecting Tobacco.—The corn root webworm, *Crambus caliginosellus* Clem., while not generally distributed over the tobacco-growing sections of the United States, is a subterranean insect of major importance in some sections and attacks and kills newly set tobacco plants. In fields intended for tobacco culture the normal agricultural practices followed in preparing the soil for the young tobacco plants to be set out result in the destruction of the wild and other host plants of the larvae. Consequently the newly set plants are fed upom immediately by the larvae that have overwintered in the soil.

For a number of years the writers have experimented in improving an insecticidal control for this webworm. In 1928 Morgan & Crumb, Jour. Econ. Ent., **21**(6): 916, mentioned the use of a poisoned bran bait flavored with nitrobenzene. This material has not been found to give consistently effective results. In 1934, 1935 and 1936 it was learned that nitrobenzene (oil of mirbane) is the most attractive material that has been tested in baits against these pests and that corn meal not only could be applied more easily than the wheat bran but apparently was more attractive to the webworms.

The following formula was used in the preparation of the bait: Paris green 1 pound, cornmeal 25 pounds, nitrobenzene 1 ounce. Best results were obtained when 15–20 pounds of this mixture were used per acre, the material being sifted upon the tobacco plants immediately after they were transplanted to the field.

J. U. Gilmore and J. Milam, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*—3-11-37.

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists
Vol. 30 June 1937 No. 3

POPULARIZING ENTOMOLOGY

THE work of entomologists is essentially a public service and is dependent almost wholly upon public support. There is no man or woman in this country who is not affected beneficially or otherwise by insects. What other line of work has a more general and vital interest? Why then should not entomologists make more serious efforts to inform the public of insect problems and what is being done to solve them?

Many of us have come to regard our jobs as finished when we find out the habits of an insect and outline control methods. Securing public interest in the problem and the general adoption of control measures is certainly an important part of our work.

The assertion was made a few years ago that agricultural research was so far ahead of the adoption of research results that it would take years to catch up. Perhaps no one wants practical application to overtake research development, but we should all like to see application follow research more closely.

Entomological work lends itself well to many forms of publicity, all of which should be employed. The radio, newspapers, magazines, motion pictures and exhibits in particular should be used more often to broaden and intensify the educational service which bulletins now render. The introduction into public schools of more work dealing with entomology, as has been done in certain states, appears to have unusual promise, not only for enabling the oncoming generation to cope more effectually with specific entomological problems, but also for developing a more intelligent interest in and increased popular support for entomological work.

Entomology is replete with interesting examples of peculiar habits, of odd adaptations, of gorgeous appearances or grotesque shapes, of intense industry, of great usefulness and of wanton destructiveness. We need to find more time and talent for weaving these facts into newspaper articles, magazine stories, radio dialogues and elementary textbooks. Information on insects appears to be readily accepted by newspapers, either as short timely statements or in the form of feature articles. A prominent member of the press suggests that newspaper men should be furnished with full information on insect problems as a background for news releases.

The cultivation of friendly cooperation with the press not only will assure the issuance of more informational material but will aid in greater accuracy of statement, so important in presenting scientific facts.

The Association of Economic Entomologists should have more publicity in connection with its meetings and a wider use of the store of information presented. The cooperation of the membership is urgently needed if this is to be brought about. Papers must be prepared early and striking portions of them put into good newspaper style, even with catchy headings. A larger publicity committee would help and each of

us should try to interest the press in our conventions. The committee is practically helpless, however, without the cooperation of all members of the Association. You are urged to do your part.

F. C. BISHOPP.—5-14-37.

Reviews

Entomological Equipment and Methods, Part II, by Alvah Peterson. Planographed by John S. Swift Co., Inc., St. Louis. 8½×11, 334 pp., 41 pls. 1937. $4.50.

This manual is a very useful and valuable contribution to entomological literature and "attempts a complete compilation of abstracts and original contributions on rearing information found in the English language." In addition it contains many abstracts of articles on marking and shipping or transporting living insects; collecting, killing, mounting and shipping insects; photographing insects and their work; and some miscellaneous notes on laboratory, field and museum technic. The abstracts are concise, well-organized and designed for aid in experimenal work and teaching research technic. References to the illustrations are cited in the abstracts. Each abstract is prefaced by the author's name, date, title of article and place of publication. In the case of an original contribution the abstract does not bear a reference to the literature. The excellent illustrations, list of coauthors at the end of each alphabetic series in the text, and a complete double index add much to the usefulness of the work.

The author has abstracted a great mass of literature in this manual, very carefully and thoroughly.

CARL J. DRAKE, *Iowa State College, Ames.*—5-12-37.

The Biological Control of an Insect in Fiji, by T. H. C. Taylor. x+239 pp., 23 plates. 1937. The Imperial Institute of Entomology, London, England.

During the last 10 years several outstanding and successful examples of applied biological control have been demonstrated in the Fiji islands. This book presents an exceptionally complete ecological picture of another successful example of biological control.

It is of particular interest and value because the problem involves the control of a native insect, a leaf-mining beetle, *Promecotheca reichi* Baly (Hispidae), of the coconut palm.This insect a few years ago was controlled by several natural native enemies. Upon the accidental introductions of a mite, *Pediculoides ventricosus,* which attacks the larvae and pupae of the beetle, the normal "multi-stage" condition of the host was changed to a "one-stage" condition. This change upset the natural balance established between the host and its parasites to such an extent that the native parasites no longer were able to check the development of the host at all times. The "one-stage" condition gave the host a chance to develop periodically to such a marked extent that it becomes a serious pest similar in many respects to numerous "one-stage" pests so common in temperate regions.

After a careful study of the biological situation established by the mite and other factors relating to the problem it was decided that the most satisfactory parasite to control the situation should possess the following characteristics: it should be an internal parasite of the larval and pupal stages, it should have a biotic potential of at least 20 and should complete its development within one month. The adult parasite should be active, capable of spreading rapidly and live for at least three weeks. Also the insect must be able to withstand the climate in Fiji.

With these predetermined characteristics in mind a search for parasites attacking closely related hosts was conducted. Four species of parasites of closely related hispids were found in Java. The most successful species in Java in the control of a "multi-brooded" hispid was not the species selected for Fiji. A less important species, *Pleutrotropis parvulus* Ferr., was chosen as the ideal parasite because it came the closest to fitting the above requirements. It was introduced, established and within six months to a year phenomenal and satisfactory control resulted.

The above summary of the problem discussed in the book suggests some of the complexities of the ecological situation the investigators encountered. From several points of view this study is one of the most scientific of all biological control investigations to date. It is a beautiful presentation of the solution of a complex problem which was investigated in an orderly and scientific manner.

In addition to relating a fascinating story on biological control the author presents, directly or indirectly, a number of important and fundamental considerations in the field of biological control. For students and investigators in this field the book is of distinct value. The methods pursued and fundamental facts taken into consideration should serve as an ideal for future work in biological control elsewhere in the world.

T. H. C. Taylor, his helpers and sponsors are to be congratulated on this outstanding investigation

The book is made up of a complete table of contents, text matter and figures, references and plates of photographs and drawings. An index would have increased the usefulness of the book.

ALVAH PETERSON, *Ohio State University*, Columbus.—4-30-37.

Fragments of Entomological History, Including Some Personal Recollections of Men and Events, by Herbert Osborn. 394 pp., front., 47 pl. 1937. Published by the author, Columbus, Ohio. $4.

This valuable contribution to the history of entomology by one of its most admired teachers has been eagerly awaited by the profession for several years. It has been an altogether worthwhile task and the book fills a unique place in this class of writings.

The author has divided his book into 12 chapters with the following headings: (1) Early Steps in Entomology—where mention is made of insect outbreaks before 1800, which contributed to the rapid development of economic entomology in the United States. (2) The Nineteenth Century—which is treated by thirds and includes a discussion of the Melshimer family, Say, Peale, Rafinesque, Harris, Haldeman, Ziegler, Walker, Agassiz, Walsh, Poey, Gundlach, Claypole and Belfrage among others. (3) Federal Service in Entomology—in which a brief historical account is given of the federal Bureau of Entomology from Glover to Strong, and the present-day organization with names of staff investigators. (4) State Entomologists, Inspectors and Quarantine Officers—in which brief historical accounts are given of the beginnings of entomological work in some of the pioneering states, with brief historical discussions of regulatory work and entomological legislation in many of the states. (5) Experiment Station Entomology—in which an account is given of the development of this section of investigation and public education, with a listing of many staff members of stations from most of the states, the order of treatment, however, being by geographical location of the states and not alphabetical nor chronological. (6) Entomological Instruction in Colleges—which brings together brief historical accounts of this phase of the subject which heretofore have been either unrecorded or were available only in widely scattered publications. (7) Entomological Societies—in which a brief historical account is given of most of the important entomological societies of the United States, founded from 1859 to 1915. (8) Entomological Publications—including historical notes about many publications and publishing societies. (9) Personal Sketches—which is the largest and most useful chapter in the book. No other historical account has included so many biographical accounts, especially of living entomologists, many with reproductions of their photographs. The author is to be congratulated on this splendid chapter. Every one, it is predicted, will find these brief, illustrated biographies interesting and useful. (10) Insect Collections—which is a good, brief discussion of the more important insect collections of the United States, with estimates of the numbers of species and specimens in most of them and the chief contributors to the collections. (11) Some Regional Notes—in which is recorded much information for the first time or previously widely scattered. (12) Miscellaneous Notes—which may be characterized similar to chapter 11. A postscript, 47 plates, and an excellent index complete the book.

The reader will note omissions of names, departments or states in discussions as predicted by the author, some mistakes in names other than those given in the errata but, in the opinion of the reviewer, these do not detract from the delightful reading afforded by the author and availability of much useful information about an even more important subject than that of insects in the study of entomology, *viz.*, entomologists. The thanks of the profession are due this beloved author for this large and valuable "fragment" out of the life and experience of one who has been such a dominant factor influencing directly and indirectly through his many students, the development of this science. It is a book entomologists will want on their desk to help connect names and faces as they read the contributions of contemporary writers.

ROGER C. SMITH, *Kansas State College, Manhattan.*—4-30-37.

Culture Methods for Invertebrate Animals, by Paul S. Galtsoff, Frank E. Lutz, Paul S. Welch and James G. Needham. xxii+590 pp. Comstock Pub. Co., Ithaca, N. Y. $4.

As indicated on the title page of this volume, it is a compendium prepared coöperatively by American zoologists under the direction of a committee from Section F of the American Association for the Advancement of Science, assisted by many specialists whose names appear in their respective contributions. These specialists number 186 and in several cases more than one topic has been dealt with by the same collaborator. To this must be added a quite considerable number of reprints of short articles or abstracts of other papers that have been added by the editors. As a consequence a most unique and valuable work has been produced which cannot fail to be a great help and time saver to every person interested in invertebrate life wherever his special field of endeavor may lie.

As might be predicted the material relating specifically to insects occupies a major part of the book, inasmuch as 260 of the 571 pages of text are strictly entomological.

Following a brief introduction by Professor Needham there is an account of collecting and rearing marine invertebrates by Galtsoff and a similar resumé dealing with terrestrial and freshwater forms by Lutz, Welch and Needham. Following these are specific chapters on divisions each dealing with one of the several phyla of invertebrates. Some 50 short discussions of one or several pages each describe methods of securing and cultivating various Protozoa, mainly free-living forms. Of direct interest to entomologists, however, is an article on the maintenance of avian malaria and others on certain flagellates. The section on nematodes, although very short, will be of use in connection with nema parasites of insects. Among the directions for the culture of crustaceans, the production of food animals like *Daphnia* is dealt with in useful detail.

The portion devoted to insects is so extensive that it would be unwise to attempt any summary in a brief review. Common laboratory insects such as cockroaches, grasshoppers, grouse locusts, clothes moths, bee-moths, flour moths, blowflies, houseflies, mealworms, grain weevils, and also, of course, *Drosophila*, are very adequately treated, and in sufficient detail to enable entomologists as well as other biological workers to breed them with a minimum of difficulty.

The methods of rearing many other miscellaneous insects with vegetarian habits such as moths, butterflies, leafhoppers, aphids, mealy bugs, scarabæid beetles, and weevils, include a great variety of procedures which should be readily adapted to the handling of any other species having similar habits. Many predatory forms are also included.

The space devoted to entomophagous parasites is unfortunately not extensive. Only a single page relates to Tachinidae although there are several short accounts of certain hymenopterous parasites.

Of particular interest are descriptions of the rearing of maggots for surgical use and the culture of sterile mosquito larvæ and a very complete account of the methods and equipment used in rearing the Rocky Mountain Spotted Fever Tick.

Many of the articles include short lists of references and there are numerous cross-references; both of these greatly enhance the usefulness of the volume, as does also a good index.

Really, little but praise can be honestly given to this useful compendium. The numerous lacunæ that are noticeable are mainly unavoidable as the editors have themselves noted in their introductory remarks, and the gaps must be filled by further experimentation. Certainly the present compilation should stimulate activities in this direction.

C. T. Brues, *Harvard University.*—3-24-37.

Obituary

William Morton Wheeler 1865–1937

The death of William Morton Wheeler occurred without warning on April 19, 1937. He succumbed in Cambridge subway station, as he was returning to Boston from Harvard University.

Professor Wheeler was 73 at the time of his death. He was born March 19, 1865, at Milwaukee, Wisconsin. He had served several institutions with distinction. Clark University gave him the Ph.D. degree in 1892, and subsequently honorary degrees of Sc.D. from Chicago, Harvard and Columbia, and LL.D. from California were conferred upon him. Professor Wheeler was also awarded the Leidy medal from the Academy of Natural Sciences of Philadelphia, and was an officer, Legion d'honneur.

Since 1933 Dr. Wheeler had been professor of entomology, *emeritus*, at Harvard, where he had been professor from 1908. He has also taught at the University of Chicago and the University of Texas, and from 1915 to 1929 was Dean of Bussey Institution, Boston.

Professor Wheeler was the author of 467 publications, 10 of which were books. He published chiefly on ants, but his works included also embryology, evolution, parasitism, and animal sociology.

A complete review of the life and works of Professor Wheeler is expected to appear in an early number of the Annals of the Entomological Society of America.

F. M. CARPENTER—5-15-37.

Current Notes

ENTOMOLOGISTS OF GEORGIA MEET APRIL 2, 1937, AT EXPERIMENT, GA.

At the invitation of Theo. L. Bissell, 13 entomologists assembled at Experiment on April 2, 1937. The meeting was called to order by the chairman, C. H. Alden, at 10 a.m., and Horace O. Lund was elected secretary. Short introductory reports by each individual on his professional history (if any), entomological activities, and special interests were followed by round-table discussions of the pests of various crops. Discussion leaders were as follows:

Paul M. Gilmer	cotton insects
Oliver I. Snapp	peach insects
Horace O. Lund	forest insects
Theo. L. Bissell	pecan insects
M. S. Yoemans (by C. H. Alden)	screw worms
C. H. Alden	vegetable insects

After the reading of Mr. Yoeman's paper on the screw worm problem, Mr. Bissell moved that the group go on record as endorsing the joint resolution passed by the state legislature of Georgia in its recent session recommending to the Secretary of Agriculture of the United States the continuance of the control program against the screw worm in those states which have recently suffered serious infestations. The motion was carried.

Dr. Franklin Sherman, of Clemson College, S. C., gave a very interesting talk on the desirability of a complete insect survey of Georgia and suggested a technic for filing the accumulated data. The idea was enthusiastically received and a committee was appointed by the chairman to consider plans for developing a survey of the insects of Georgia, the committee members being: Horace O. Lund, chairman; Theo. L. Bissell, P. W. Fattig, Paul M. Gilmer and Oliver I. Snapp. It was suggested that either the University of Georgia at Athens or the Experiment Station at Experiment would be the best place to accumulate the records.

Mr. Gilmer moved that the secretary be instructed to contact all interested persons to determine their attitude toward the organization of a Georgia Entomological Society to include in its membership all Georgians (either professionals or amateurs) interested in insects, meetings to be held annually in conjunction with the Georgia Academy of Science meetings. Motion was adopted unanimously.

Motion for adjournment was adopted.

The roll of those present was as follows:

Alden, C. H., Cornelia
Bissell, Theo. L., Experiment
Bushnell, R. J., Athens
Byrd, E. E., Athens
Cartwright, O. L., Clemson, S. C.
Fattig, P. W., Atlanta
Gilmer, Paul M., Tifton
Lanier, Mrs. L. Fielding, Sylvania
Lund, Horace O., Athens
Sherman, Franklin, Clemson, S. C.
Snapp, Oliver I., Fort Valley
Thomson, J. R. Jr., Fort Valley
Webb, J. E., Jr., Cornelia

(Signed) HORACE O. LUND, *Secretary*

PEST CONTROL OPERATORS, better known as pest exterminators, met at Purdue University, Lafayette, Ind., January 18–22, for a Pest Control Operators' Conference or short course. Eighty-one persons from 14 states registered for the conference, which was a pioneering event and promises to be a worth-while annual affair.

DR. ROWLAND W. LEIBY has become assistant professor of entomology in the extension department of Cornell University, to fill the vacancy caused by the death on January 11 of Professor Cyrus R. Crosby.

THE CROP PROTECTION INSTITUTE is again publishing its mimeographed circular of timely information, which had previously been compiled so successfully by W. A. McCubbin. Entomological members of the Board of Governors of the C.P.I.—W. C. O'Kane, C. H. Richardson and J. J. Davis—who represent the American Association of Economic Entomologists, urge support from entomologists, as well as plant pathologists and insecticide chemists. Active membership in the Crop Protection Institute is $1 per year, payable to Paul Moore, 2101 Constitution Avenue, Northwest, Washington, D. C. Active membership not only represents moral support of the Institute, which has been a big factor in the development of insecticides and fungicides and in maintaining a contact with the insecticide and fungicide industries, but in addition members receive the C.P.I. circular and the bulletins as printed by the Institute, which now number more than 60.

DR. EDITH M. PATCH RETIRES FROM UNIVERSITY OF MAINE FACULTY

Retirement of Dr. Edith M. Patch, founder of the University of Maine's department of Entomology, will take place this June, according to announcement early in April by Dr. Arthur A. Hauck, president of Maine.

Foremost entomologist, fellow of the Entomological Society of America and its first woman president, Dr. Patch has gathered numerous honors in her 34 years of teaching at Maine. Her international reputation is based on her study of aphids. She is a fellow of the AAAS, member of the American Association of Economic Entomologists, American Society of Naturalists, and National Council of Supervisors of Elementary Science, and president of the American Nature Study Society.

Nature study is one of the fields in which Dr. Patch is well known, both through her activities in organizations and through her 15 books on nature studies for children. She is also the author of many scientific articles and bulletins.

Miss Patch was born at Worcester, Mass., was graduated from the University of Minnesota in 1901, received her master's degree at Maine, 1910, and her doctorate at Cornell, 1911. Her honor fraternities include Phi Beta Kappa, Phi Kappa Phi, Phi Sigma, Pi Gamma Mu, and Sigma Xi.

NEWELL ENTOMOLOGICAL SOCIETY SPONSORS FLORIDA ENTOMOLOGICAL CONFERENCE AND HERBERT OSBORN BIRTHDAY PARTY

The Newell Entomological Society at the University of Florida sponsored a meeting of all Florida entomologists at Gainsville, March 19 and 20, 1937. In addition to the two-day program of papers and discussions a banquet in observance of the birthday of Herbert Osborn was held Friday evening, March 19.

Thursday evening preceding the conference, the Society and the Alpha Gamma Rho fraternity sponsored a smoker for visiting entomologists and friends.

Twenty-three addresses were scheduled for the morning and afternoon sessions, and two speakers responded to toastmaster Dr. H. Harold Hune at the banquet, on the life and teachings of Dr. Osborn. The two speakers were Dr. Wilmon Newell, Dean of the University of Florida College of Agriculture and Dr. E. W. Berger, Florida State Plant Board Entomologist.

The sessions closed with a business meeting of the Florida Entomological Society at noon Saturday, March 20.

Chairman of the conference was John T. Creighton, Professor of Economic Entomology, University of Florida. P. S. Arey, president, Juliet Carrington, secretary, and T. Roy Young, member, all of the Newell Entomological Society, were vice chairmen assisting Professor Creighton.

"THE ENTOMOLOGY ACT OF 1937" of the State of Georgia establishes a State Department of Entomology and repeals all previous legislation on the subject of the state entomologist except the act approved March 28, 1935, relating to the fraudulent sale of plants. It also repeals certain chapters of the code of 1933 relating to nurserymen.